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Water Quality Trends of the Illinois Waterway System Upstream of Peoria Including the Chicago Metropolitan Area

by

Robert S. Larson

Prepared for the
Metropolitan Water Reclamation District of Greater Chicago

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Illinois State Water Survey
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Contents

Abstract

The long-term temporal trends of water quality in the Illinois Waterway system upstream of Peoria are described in this report. The time period investigated was from 1965 to 1995. The seasonal Kendall trend test was used to detect statistically significant trends. A related test, the seasonal Kendall slope estimator, was used to calculate the magnitude of the trend. Box plots were also used to visualize differences in data over time.

The water quality analytes considered in this report include dissolved oxygen, ammonia-nitrogen, nitrate and nitrite-nitrogen, total Kjeldahl nitrogen, total phosphorus, sulfate, turbidity, total suspended solids, fecal coliform, cyanide, and phenol.

Water quality was generally found improved at all stations. Substantial improvements were found at most stations for dissolved oxygen, the nitrogen species, phenol, and cyanide concentrations. Fecal coliform densities generally decreased at most locations. Little or variable change was found for turbidity, total suspended solids, and total phosphorus concentrations. Increasing trends were detected for sulfate concentrations.

Introduction

The Illinois Waterway consists of the Illinois River, a portion of the Des Plaines River, and the Chicago-area waterways, which include the Cal-Sag Channel, Chicago Sanitary and Ship Canal, the South Branch Chicago River, North Branch Chicago River, Chicago River, North Shore Channel, and the Calumet and Little Calumet Rivers.

Reports by early explorers of the Illinois River tell of a river that supported great populations of fish and wildlife. In the early 19th century, Chicago industries and families dumped their wastes into the small streams and rivers that drained into Lake Michigan, the city water supply. Epidemics of diseases related to polluted water, such as cholera, occasionally occurred. Temporary relief came in 1848 when the Illinois-Michigan Canal was opened. Connecting the Chicago River with the Illinois River, the canal allowed wastes from Chicago to be transported downstream to the Illinois River, protecting the Chicago water supply. As Chicago continued to grow, the narrow and shallow Illinois-Michigan Canal proved inadequate to transport all of the city's waste. By the end of the 19th century, cholera epidemics were occurring again.

In 1900, the much larger Chicago Sanitary and Ship Canal replaced the Illinois-Michigan Canal. Several authors have documented the deplorable conditions of the Illinois Waterway during the early part of the 20th century (Illinois State Water Survey, 1903; Greenfield et al., 1924). The Upper Illinois River was so polluted by 1912 that it was practically devoid of all fish life. The river carried waste equivalent to the volume produced by 6.2 million people in 1922. Parts of the river were hypoxic (i.e., almost totally devoid of oxygen), especially in the summer months.

Improvements in waste treatment throughout the 20th century have reduced the waste load carried by the Illinois River. By 1960 the waste load had been reduced to 28 percent of the 1922 amount, and by 1981 the waste load was further reduced to 9 percent of the 1922 amount (Talkington, 1991).

Other factors have contributed to the degradation of the quality of water in the Illinois Waterway during the 19th and 20th centuries, including the construction of numerous dams to maintain water levels for commercial navigation, urbanization, and other land-use changes within the basin. Additional sources of pollution included agricultural runoff and atmospheric deposition.

Since the passage of the Illinois Environmental Protection Act in 1970 and the Federal Water Pollution Control Act of 1972, a great deal of pollution control activities have occurred to help restore the water quality of the Illinois Waterway.

Treated domestic and industrial wastewater from the Chicago area is still a primary source of water in the Illinois Waterway. Today, however, the treated effluent is of a very high quality. Improvements to the wastewater reclamation plants are documented in Terrio (1994). In addition to the plant improvements, the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) also has constructed several innovative pollution control projects to improve water quality. Included in these are the Tunnel and Reservoir Project (TARP) and the Sidestream Elevated Pool Aeration (SEPA) stations.

The TARP is a series of tunnels and surface reservoirs that store urban runoff until it can be treated at existing water reclamation plants. Prior to the development of TARP, rainfall events caused combined sewers to overflow into Chicago-area waterways. These overflows caused about 100 spills of raw sewage and stormwater each year (Butts and Shackleford, 1992). The initial implementation of TARP occurred in 1985.

The SEPA stations supplement dissolved oxygen (DO) in the Calumet Waterway System by pumping water from the Calumet Waterway to a series of elevated pools connected by weirs. The DO in the water is replenished as it is pumped by screw pumps and flows over the weirs before being returned to the waterway. The MWRDGC has constructed five SEPA stations. One station is located at the junction of the Cal-Sag Channel and the Chicago Sanitary and Ship Canal and aerates water water withdrawn

from both bodies of water. The other four SEPA stations are located on the Cal-Sag Channel, Little Calumet River, and Calumet River.

Despite the severe pollution that occurred during much of the 19th and 20th centuries, water quality in the Illinois Waterway System has improved, and the biota has at least partially recovered. Lerczal et al. (1992, 1993) compared the results of fish collected from the Illinois River in 1963 to those collected in 1992. They determined that the river now supports a much healthier fish population than it did in the 1960s. The earlier collection was dominated by pollution-tolerant, nonnative species such as carp and goldfish. Recent collections included a more balanced population of native species. The improvement was most evident in the Illinois River above the Starved Rock Lock and Dam, at which 95.8 percent of the fish collected in 1963 consisted of only four species. In 1992, 13 species comprised 95.4 percent of the fish collected, and the pollution-tolerant, nonnative species were reduced to a minor component of the collection. Lerczal et al. (1992, 1993) also noted that the occurrence of external abnormalities of the fish, such as sores and tumors, was much lower in 1992 compared to 1963. A key to the improvement in the ecological conditions has been the increase in DO. The waterway is no longer chronically hypoxic.

Due to the presence of the navigation dams, alterations in flow regimes, and changes in land use, a full recovery of the Illinois Waterway to pre-19th century conditions is not a practical objective. However, the waterway is once again considered to be an important natural resource of Illinois, and an important recreational destination.

An important tool in the recovery of the waterway has been the collection of water quality data, which has aided scientists and decision makers by gauging the progress that has been made in the waterways recovery. Numerous agencies, including state and federal agencies, universities, and municipal water reclamation districts, have collected large amounts of water quality data from the Illinois Waterway beginning with the opening of the Chicago Sanitary and Ship Canal.

Objectives

The objectives of this study were two-fold. The first objective was to collect and compile available water quality, sediment quality, and biological data collected by a variety of public and private entities since 1965. A relational database was used to store the subject data, and computer programs were developed to search and extract data easily. Table 1 lists the agencies and private firms whose data are included in the database.

The second objective of this project, and the focus of this report, was to describe long-term temporal trends of water quality in the Illinois Waterway upstream of Peoria from 1965-1995. Most activity in restoring the river, particularly since the enactment of the Illinois Environmental Protection Act of 1970 and the Federal Water Pollution Control Act of 1972, has taken place in this time period.

Acknowledgments

The views expressed in this report are those of the author and do not necessarily reflect the views of the sponsor or the Illinois State Water Survey.

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Table 1. Sources of Data Contained in Relational Database of Water Quality, Sediment Quality, and Biological Data

Metropolitan Water Reclamation District of Greater Chicago
Illinois State Water Survey
Illinois Natural History Survey
Illinois Department of Natural Resources
Illinois Environmental Protection Agency
United States Army Corps of Engineers
United States Geological Survey
Illinois Power Company
Commonwealth Edison
Bradley University
Daily and Associates
Donahue and Associates
Wapora, Inc.
Environmental Science and Engineering, Inc.

Methodology

Station Selection

Data collected by a number of agencies and institutions were considered for inclusion in the trend analysis. The selection of the stations used in this report was based on several criteria, including:

- length of continuous record (> ten years)
- regular sample frequency (> nine samples per year)
- adherence to a quality assurance program
- variety of parameters measured
- geographic location.

Many stations were eliminated because data were not collected for a sufficient period of time. Fourteen stations were selected and are listed in table 2, with the period for which data are available. The locations of these stations are shown in figure 1.

The MWRDGC has collected a considerable amount of data, so a large number of stations were available in the Chicago-area. Eleven of these stations were selected. Data was available for these stations from 1974-1995. Data for phenol and ammonia-nitrogen (NH_4-N), however, were only available for 1974 - 1993. In addition, the Illinois Environmental Protection Agency (IEPA) data collection station in the Chicago Sanitary and Ship Canal at Romeoville was selected. Data for most parameters at this station were available from 1978-1995

In the Illinois Waterway below Lockport, long-term data were available at few locations. Only two stations satisfied the criteria for selection: the United States Geological Surveys (USGS) station on the Illinois River at Marseilles and the Illinois State Water Surveys (ISWS) station on Lake Peoria. Data were available from the USGS station from 1970-1995, and from the ISWS station from 1965-1995.

Table 2. Trends Analysis for Stations M-0 – M-10, I-11, G-12, and S-13, Data Source, and Period of Record

Station	*Station name*	*Source*	*Period of record*
M-0	North Shore Channel @ Touhy Ave	MWRDGC	1974 - 1995
M-1	North Branch Chicago River @ Grand Ave.	MWRDGC	1974 - 1995
M-2	South Branch Chicago River @ Madison St.	MWRDGC	1974 - 1995
M-3	South Branch Chicago River @ Damen Ave.	MWRDGC	1974 - 1995
M-4	Chicago Sanitary and Ship Canal @ Cicero Ave.	MWRDGC	1974 - 1995
M-5	Chicago Sanitary and Ship Canal @ Harlem Ave.	MWRDGC	1974 - 1995
M-6	Chicago Sanitary and Ship Canal @ Route 83	MWRDGC	1974 - 1995
M-7	Cal-Sag Channel @ Ashland Ave.	MWRDGC	1974 -1995
M-8	Cal-Sag Channel @ Cicero Ave	MWRDGC	1974 - 1995
M-9	Cal-Sag Channel @ Route 83	MWRDGC	1974 - 1995
M-10	Chicago Sanitary and Ship Canal @ Stephens Street	MWRDGC	1974 - 1995
I-11	Chicago Sanitary and Ship Canal @ Romeoville	IEPA	1968 - 1995
G-12	Illinois River @ Marseilles	USGS	1970 - 1995
S-13	Illinois River @ Peoria	ISWS	1965 - 1995

NOTES :
MWRDGC = Metropolitan Water Reclamation District of Greater Chicago
IEPA = Illinois Environmental Protection Agency
USGS = United States Geological Survey
ISWS = Illinois State Water Survey

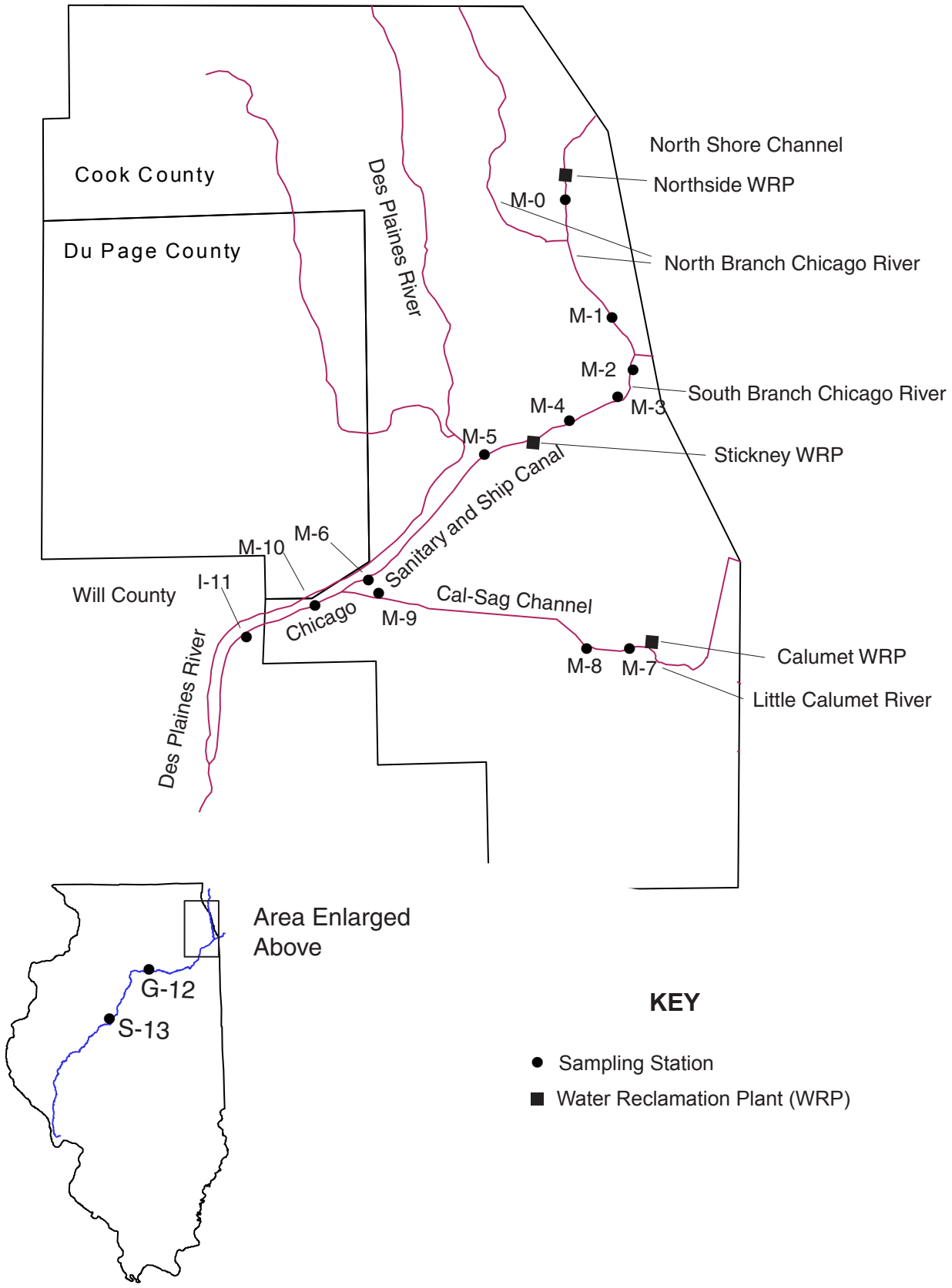

Figure 1. Location of sampling stations

The MWRDGC collects water quality data by grab samples obtained at midchannel and at a depth of 3 feet below the water surface. The ISWS data used in this study were collected in a similar manner. Samples collected by the IEPA and USGS were composite samples integrated by depth and width.

Eleven water quality parameters (see table 3) were selected to test for trends. Additional parameters, including metallic elements, such as lead, arsenic, copper, and chromium, were considered for inclusion but eliminated because of the low frequency of samples above the element's minimum detection limit. Sediment samples also were considered, but stations at which samples had been collected for a sufficient amount of time and frequency could not be identified.

Statistical Methods

The quality of river water is the product of stochastic processes that result in measures of water quality which often exhibit traits such as nonnormality, serial correlation, seasonality, skewness, or some combination of these traits. These conditions often make statistical analysis problematic. Of the commonly measured water quality variables, only temperature, pH, and DO are typically normal or near-normal (Hirsch and Slack, 1984). Statistical analysis of water quality data for constituents such as metals is further complicated by the presence of values below minimum detection limits. In particular, this is a problem when multiple minimum detection limits occur for a given constituent.

When the assumptions required by parametric statistical tests cannot be met, some type of nonparametric test is often used. A nonparametric test that has shown great utility in the detection of temporal trends of water quality data is the seasonal Kendall trend test (Hirsch et al., 1982; Hirsch and Slack, 1984). This test is a variation of the Kendall *tau* (Kendall, 1975), which has been modified specifically for use with water quality data. In particular, it has been modified so it is insensitive to seasonality. It assumes that the random variable is independently and identically distributed.

Table 3. Water Quality Constituents Selected for Trend Analysis and Illinois Pollution Control Board Water Quality Standards in Effect in 1995.

Analyte	*General use standard*	*Secondary Contact Standard*
Dissolved Oxygen (DO)	5.0 mg/L	4.0 or 3.0 mg/L
Ammonia-nitrogen (NH_4-N)	15 mg/L maximum with unionized ammonia < 0.04 mg/L as N	Un-ionized ammonia < 0.1 mg/L as N
Total Kjeldahl Nitrogen (TKN)	No Standard	No Standard
Total Phosphorus (P)	No Standard	No Standard
Sulfate (SO_4)	No Standard	No Standard
Turbidity	No Standard	No Standard
Total Suspended Solids (TSS)	No Standard	No Standard
Fecal Coliforms	200 colonies/ml	No Standard
Cyanide	0.022 mg/L (WAD)	0.1 mg/L
Phenol	0.1 mg/L	0.3 mg/L

This test is computed by comparing all possible ordered pairs for each season. For monthly data, for example, it determines if a trend exists individually for each month of the year, then aggregates the monthly test scores into an overall value.

However, the seasonal Kendall trend test only indicates whether or not a trend exists and the significance level of the trend. A related procedure, the seasonal Kendall slope estimator (Hirsch et al., 1982), was used to calculate the magnitude of the trend. It is computed as the median of the slopes of the ordered pairs of values used to compute the seasonal Kendall statistic, and is used in this report as an estimate of the annual average change of an analyte.

Also useful for the detection of temporal trends are a variety of graphical techniques. In particular, box plots are useful for visually displaying the differences in data from different periods (see figure 2 for an example). Box plots visually indicate the magnitude of the data set, the variation of the data, and the presence of outlier values. It also is useful to explore changes in regulatory compliance over time. The Illinois Pollution Control Board (IPCB) designates most water bodies within the State of Illinois as General Use waters, which are afforded the strictest level of protection. The USGS station at Marseilles and the ISWS station at Peoria are both located in areas designated for General Use. The artificial canal system in the Chicago area is designated as "Secondary Contact and Indigenous Aquatic Life" and are subject to less strict instream water quality standards. All of the MWRDGC stations used in this report and the IEPA station at Romeoville are located in Secondary Contact waters. The IPCB has published standards for five of the water quality constituents considered in this study. These are DO, NH_4-N (converted to an un-ionized ammonia value), phenol, cyanide, and fecal coliforms.

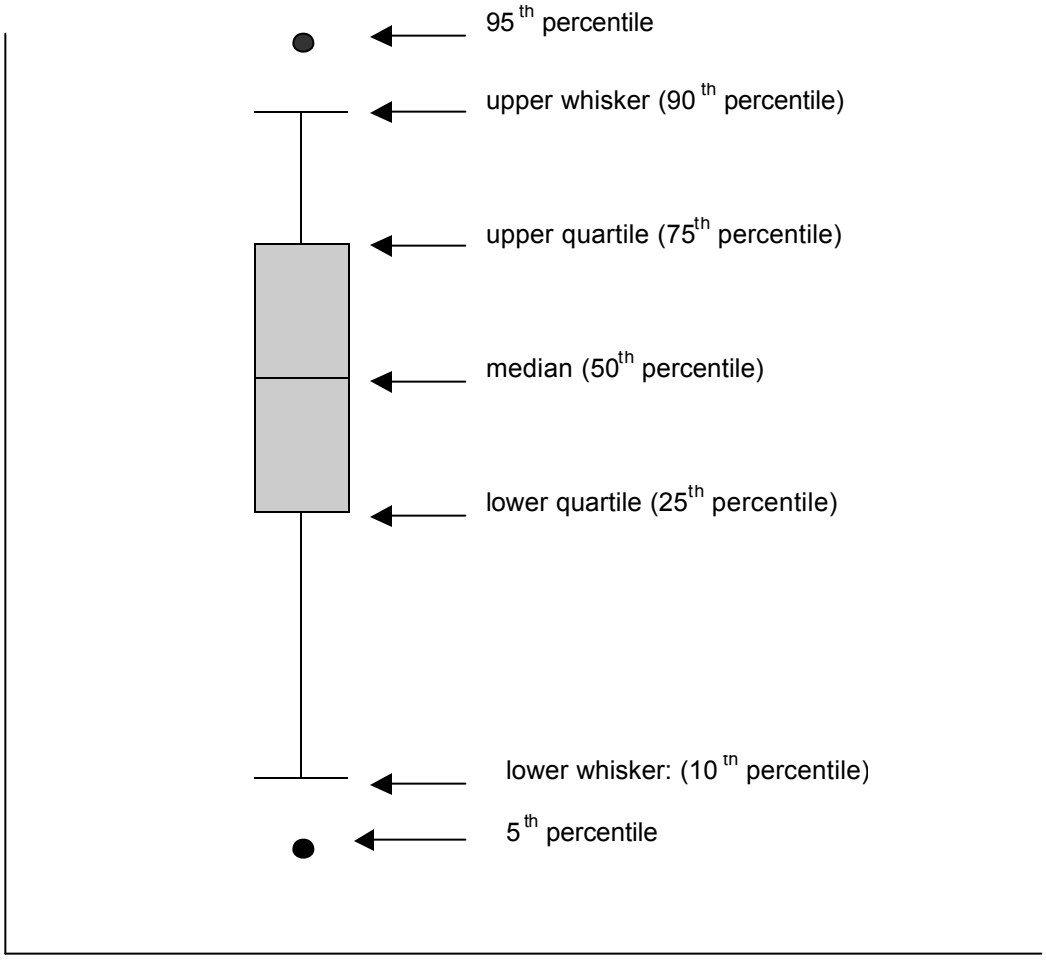

Figure 2. Explanation of a box plot. The 25th and 75th percentiles are located at the top and lower edges of the box, respectively. The line through the box indicates the median. The upper whisker indicates the 90th percentile and the lower whisker indicates the 10th percentile. Round points represent the 5th and 95 percentiles.

Results

Results of the seasonal Kendall trend test and the Kendall slope estimator are given in tables 4-10. These tables indicate whether the trend is increasing or decreasing, and they give the level of significance (**p**) of the test and the slope estimate. For most constituents, a decreasing trend indicates improved water quality. For DO, however, an increasing trend is associated with improved water quality. For nitrate and nitrate nitrogen (NO_3+NO_2-N), an increasing trend may also be associated with improved water quality, if it is accompanied by a decreasing trend in NH_4-N (indicating nitrification) .

Significance values of 0.1 or less are considered to be statistically significant. The slope estimate is displayed only for those instances in which the **p**-value showed the trend to be statistically significant at the 90 percent level of confidence.

North Shore Channel/North Branch Chicago River (Stations M-0 and M-1)

Results of the seasonal Kendall trend test and the Kendall slope estimator for the North Shore Channel at Touhy Ave. (M-0) and the North Branch Chicago River at Grand Ave. (M-1) stations are given in table 4. Box plots are given in appendix A for station M-0 and appendix B for station M-1.

The seasonal Kendall test showed a significant upward trend in DO concentration, indicating improved water quality, at station M-1, although no statistically significant trend was detected at station M-0. These findings also are evident in the box plots in figures A-1 and B-1. DO measurements below the 4.0 milligrams per liter (mg/L) Secondary Contact standard seldom occur at station M-0. At station M-1, measurements below the DO standard are more frequent, but their frequency is decreasing. Prior to 1988, 66 percent of DO measurements were less than 4.0 mg/L, and only 11 percent of the measurements since 1988 have been below the standard.

Table 4. Results of the Seasonal Kendall Trend Test and Slope Estimator for Stations M-0 (North Shore Channel at Touhy Ave.) and M-1 (North Branch Chicago River at Grand Ave.), 1974 - 1995

	M-0			*M-1*		
Parameter	*Direction*	*p-value*	*Slope*	*Direction*	*p-value*	*Slope*
DO	ns			+	<0.001	0.127
NH_4-N	-	<0.001	-0.220	-	<0.001	-0.196
NO_3+NO_2-N	+	< 0.001	0.062	+	0.003	0.077
TKN	-	<0.001	-0.171	-	<0.001	-0.211
Total P	-	<0.001	-0.021	-	<0.001	-0.035
SO_4	ns			+	<0.001	2.000
Turbidity	ns			ns		
TSS	ns			-	0.001	-0.250
Fecal coliforms	+	<0.001	642	-	0.002	-300
Cyanide	-	<0.001	-0.001	-	<0.001	-0.0004
Phenol	-	<0.001	-0.429	-	0.001	-1.143

NOTES:
DO = dissolved oxygen
NH_4-N = ammonia-nitrogen
NO_3+NO_2-N = nitrate and nitrite-nitrogen
TKN = total Kjeldahl nitrogen
P = phosphorus
SO_4 = sulphate
TSS = total suspended solids
ns = not significant
+ = increasing trend
- = decreasing trend

Statistically significant downward trends of NH_4-N concentrations were detected at both stations. Estimated changes of NH_4-N were similar at both stations, ranging from 0.196 mg/L per year at station M-1 to 0.220 mg/L per year at station M-0. These trends also are evident in the box plots (figures A-2 and B-2).

Significant increasing trends of NO_3+NO_2-N were found at both stations, indicating improved water quality and corresponding to the decreases in NH_4-N at these stations. Changes in NO_3+NO_2-N were 0.062 mg/L per year at station M-0 (figure A-3) and 0.077 mg/L per year (figure B-3) at station M-1.

Statistically significant decreasing trends of total Kjeldahl nitrogen (TKN) were found at both stations. Annual median TKN concentrations (figures A-4 and B-4) were sometimes above 6 mg/L in the 1970s, but all annual medians in the 1990s were less than 3 mg/L.

Downward trends of total phosphorus (P) (figures A-5 and B-5) were statistically significant at both stations, falling an average of 0.021 mg/L and 0.035 mg/L per year at station M-0 and M-1, respectively.

A statistically significant increasing trend in sulfate (SO_4) was found at station M-1, but no significant trend was found at station M-0. Box plots of SO_4 concentrations for the stations are given in figures A-6 and B-6.

No significant trend in turbidity was found at either station. Box plots are shown in figures A-7 and B-7.

Figures A-8 and B-8 show changes in TSS concentrations at stations M-0 and M-1. A significant decreasing trend was found at station M-1, but no trend was detected at station M-0.

Figure A-9 shows a substantial increase in fecal coliform densities at station M-0 starting in 1984; this corresponds to the cessation of effluent chlorination in 1984 at the nearby Northside Water Reclamation Plant. An increasing trend in fecal coliform densities was found at station M-0, and a decreasing trend was found at station M-1 (figure B-9).

Decreases in cyanide were statistically significant at both stations (figures A-10 and B-10). No cyanide concentrations greater than the 0.1 mg/L Secondary Contact standard were observed at either station, as shown by the box plots in figures A-10 and B-10.

Statistically significant decreases in phenol concentrations were found at both stations (figures A-11 and B-11). None of the observed concentrations exceeded the 300 :g/L Secondary Contact standard.

South Branch Chicago River (Stations M-2 and M-3)

Results of the seasonal Kendall trend test and the Kendall slope estimator for the Madison Ave. (M-2) and Damen Ave. (M-2) stations on the South Branch Chicago River are given in table 5. Box plots are given in appendix C for station M-2 and in appendix D for station M-3.

Dissolved oxygen concentrations below the Secondary Contact standard occurred fairly regularly at stations M-2 and M-3 in the 1970s and early 1980s (figures C-1 and D-1). Such values comprised 26 percent and 49 percent of samples from this period at stations M-2 and M-3, respectively. Since 1986, less than 1 and 3 percent of the samples collected at stations M-2 and M-3, respectively, have been below the Secondary Contact DO standard.

Table 5. Results of the Seasonal Kendall Trend Test and Slope Estimator for Stations M-2 (South Branch Chicago River at Madison Ave.) and M-3 (South Branch Chicago River at Damen Ave.), 1974 - 1995

	M-2			*M-3*		
Parameter	*Direction*	*p-value*	*Slope*	*Direction*	*p-value*	*Slope*
DO	+	<0.001	0.129	+	<0.001	0.194
NH_4-N	-	<0.001	-0.122	-	<0.001	-0.15
NO_3+NO_2-N	ns			+	0.024	0.039
TKN	-	<0.001	-0.133	-	<0.001	-0.143
Total P	-	<0.001	-0.027	-	<0.001	-0.022
SO_4	ns			+	<0.001	0.278
Turbidity	-	<0.004	-0.167	+	<0.001	0.200
TSS	ns			ns		
Fecal coliforms	-	<0.001	-243	-	0.002	-300
Cyanide	-	<0.001	-0.0004	-	<0.001	-0.0003
Phenol	-	<0.001	-0.429	-	0.001	-1.143

NOTES:
DO = dissolved oxygen
NH_4-N = ammonia-nitrogen
NO_3+NO_2-N = nitrate and nitrite-nitrogen
TKN = total Kjeldahl nitrogen
P = phosphorus
SO_4 = sulphate
TSS = total suspended solids
ns = not significant
+ = increasing trend
- = decreasing trend

Statistically significant downward trends of NH_4-N concentrations were detected at both stations. The NH_4-N decreases were similar at the two stations, ranging from 0.122 mg/L per year at station M-2 to 0.150 mg/L per year at station M-3.

No significant trend in NO_3+NO_2-N was found at station M-2 (figure C-3). A statistically significant increase of 0.039 mg/L per year was found at station M-3 (figure D-3).

Statistically significant downward trends of TKN concentrations were detected at both stations. The TKN concentrations have decreased 0.133 and 0.143 mg/L per year at stations M-2 (figure C-4) and M-3 (figure D-4), respectively.

Statistically significant downward trends of P were found at both stations M-2 and M-3. Decreases averaged 0.027 mg/L per year at station M-2 and 0.022 mg/L per year at station M-3. These trends also are evident in the box plots given in figures C-5 and D-5.

Increasing trends of SO_4 concentrations were statistically significant at station M-3 only. Box plots of SO_4 (figures C-6 and D-6) for both stations show increasing concentrations from 1983 to about 1990.

Significant but small trends in turbidity concentrations were found at both stations (figures C-7 and D-7). An upward trend was found at station M-2, and a downward trend was found at station M-3.

No trends were found for total suspended solids (TSS) at either station (figures C-8 and D-8).

Significant downward trends in fecal coliform densities were found at both stations (figures C-9 and D-9). A decrease of 243 colonies per year has occurred at station M-2, and a decrease of 300 colonies per year was found at station M-3.

Downward trends in cyanide concentrations were significant at both stations. Concentrations decreased at a rate of 0.0004 mg/L per year at station M-2 and 0.0004 mg/L per year at station M-3. No samples from either station exceeded the 0.1 mg/L Secondary Contact standard (figures C-10 and D-10).

Decreasing trends in phenol concentrations were significant at both stations. Decreases ranged from 1.143 µg/L per year to 1.200 µg/L per year. Box plots of phenol concentrations (figures C-11 and D-11) show that a step-increase occurred between 1979 and 1981, followed by a step decrease between 1986 and 1987.

Chicago Sanitary and Ship Canal Upstream of Cal-Sag Channel (Stations M-4, M-5, and M-6)

Results of the seasonal Kendall trend tests for the Chicago Sanitary and Ship Canal stations at Cicero Ave. (M-4), Harlem Ave. (M-5), and Route 83 (M-6) are listed in table 6. Box plots are given in appndices E, F, and G for stations M-4, M-5, and M-6, respectively.

An increasing trend in DO concentrations was detected at all three stations. Median increases ranged from 0.117 mg/L per year at station M-5 to 0.155 mg/L per year at station M-6. The frequencies of DO measurements below the Secondary Contact standard of 4.0 mg/L has been substantially reduced, as shown in figures E-1, F-1, and G-1. In the late 1970s and early 1980s, it was not uncommon for 30 to 70 percent of the DO measurements taken at stations M-4 and M-5 to be below the standard. Since 1986, only 3 percent of the samples have exceeded the standard, and no violations have occurred in most years.

Decreasing trends of NH_4-N were found at all three stations (figures E-2, F-2, and G-2). Reductions were greatest (0.171 mg/L per year) at station M-5. The smallest decrease (0.124 mg/L per year) occurred at station M-4.

Table 6. Results of the Seasonal Kendall Trend Test and Slope Estimator for Stations M-4 (Chicago Sanitary and Ship Canal at Cicero Ave.), M-5 (Chicago Sanitary and Ship Canal at Harlem Ave.), and M-6 (Chicago Sanitary and Ship Canal at Route 83), 1974 - 1995

	M-4			*M-5*			*M-6*		
Parameter	*Direction*	*p-value*	*Slope*	*Direction*	*p-value*	*Slope*	*Direction*	*p-value*	*Slope*
DO	+	<0.001	0.186	+	<0.001	0.117	+	<0.001	0.155
NH_4-N	-	<0.001	-0.140	-	<0.001	-0.171	-	<0.001	-0.124
NO_3+NO_2-N	+	<0.001	0.051	+	0.002	0.083	ns		
TKN	-	<0.001	-0.140	-	<0.001	-0.133	-	0.002	-0.083
Total P	-	<0.001	-0.019	-	0.037	-0.006	-	0.013	-0.007
SO_4	+	0.069	0.375	ns			ns		
Turbidity	+	0.027	0.143	ns			ns		
TSS	-	0.052	-0.1875	-	<0.001	-0.308	-	<0.001	-0.313
Fecal coliforms	-	<0.001	-70	ns			ns		
Cyanide	-	<0.001	-0.0004	-	<0.001	-0.007	-	<0.001	-0.0004
Phenol	-	0.009	-0.294	ns			-	0.048	-0.272

NOTES:
DO = dissolved oxygen
NH_4-N = ammonia-nitrogen
NO_3+NO_2-N = nitrate and nitrite-nitrogen
TKN = total Kjeldahl nitrogen
P = phosphorus
SO_4 = sulphate
TSS = total suspended solids
ns = not significant
+ = increasing trend
- = decreasing trend

Increasing trends in NO_3+NO_2-N were statistically significant at stations M-4 and M-5 (figures E-3 and F-3). The increase averaged 0.051 mg/L per year at station M-4 and 0.083 mg/L per year at station M-5. No significant trend was found at station M-6 (figure G-3).

Statistically significant decreasing trends in TKN concentrations were found at all three stations (figures E-4, F-4, and G-4). Decreases were greater at stations M-4 and M-5 (0.140 and 0.133 mg/L per year) than at station M-6 (0.083 mg/L). Significant downward trends in total P concentrations were found at all three stations (figures E-5, F-5, and G-5). The rate of decrease was greatest (0.019 mg/L per year) at station M-4. Stations M-5 and M-6 exhibited decreases of 0.006 and 0.007 mg/L per year, respectively.

A significant upward trend in SO_4 was found at station M-4 (figure E-6) only, where a change of 0.375 mg/L per year was found. No significant trends were found at station M-5 or M-6 (figures F-6 and G-6).

A significant trend of turbidity was detected at station M-4 (figure (E-7) only. Turbidity values at this station have increased at a rate of 0.143 nephelometric turbidity units (NTU) per year. No trends were observed at stations M-5 and M-6 (figures F-7 and G-7).

Statistically significant downward trends in TSS were found at all three stations (figures E-8, F-8, and G-8). Stations M-5 and M-6 exhibited the greatest decrease rates (0.308 and 0.313 mg/L per year). The decrease rate at station M-4 was 0.188 mg/L per year.

Fecal coliform densities exhibited statistically significant downward trends at stations M-4 (figure E-9) only. No significant trends were found at stations M-5 or M-6 (figure F-9 and G-9). Examination of the box plots for these stations reveals that samples with low densities (less than 100 colonies/100 milliliters or mL) were common prior to

1984. Starting in 1984, the MWRDGC ceased chlorinating the effluents from the three major plants, and the low-density samples became a rare occurrence. This is especially evident at station M-5, which is a short distance downstream of the Stickney Water Reclamation Plant (WRP). This operational change, however, did not significantly change the median bacterial densities at either station.

Significant downward trends were detected for cyanide concentration at all three stations (figures E-10, F-10, and G-10). The decrease rates ranged from 0.0004 mg/L per year at station M-4 and M-6 to 0.0007 mg/L per year at station M-5. No sample from these three stations exceeded the 0.1 mg/L Secondary Contact standard.

The seasonal Kendall trend test detected significant downward trends in phenol at stations M-4 and M-6. No significant trend was found at station M-5. Examination of the box plots (figures E-11, F-11, and G-11) show that annual median concentrations were elevated from 1981 to 1985 at stations M-4 and M-6. Only one phenol sample from the three stations has exceeded the 300 µg/L Secondary Contact standard. This sample was taken from station M-5 in 1983.

Cal-Sag Channel (Stations M-7, M-8, and M-9)

Results of the seasonal Kendall test for stations at Ashland Ave. (M-7), Cicero Ave. (M-8) and Route 83 (M-9) on the Cal-Sag Channel are listed in table 7. Box plots are given in figures appendix H for station M-7, appendix I for station M-8, and appendix J for station M-9.

Significant increasing trends of DO concentration were detected at all three stations (figures H-1, I-1, and J-1). Increases ranged from 0.188 mg/L per year at station M-7 to 0.280 mg/L per year at station M-8. Rates of improvement range from 0.094 mg/L per year at station M-7 to 0.163 mg/L per year at station M-8. Although great improvements have been made in maintaining DO concentrations above the 3.0 mg/L

Table 7. Results of the Seasonal Kendall Trend Test and Slope Estimator for Stations M-7 (Cal-Sag Channel at Ashland Ave.), M-8 (Cal-Sag Channel at Cicero Ave.), and M-9 (Cal-Sag Channel at Route 83), 1974 - 1995

Parameter	*M-7*			*M-8*			*M-9*		
	Direction	*p-value*	*Slope*	*Direction*	*p-value*	*Slope*	*Direction*	*p-value*	*Slope*
DO	+	<0.001	0.094	+	<0.001	0.163	+	<0.001	0.140
NH_4-N	-	<0.001	-0.398	-	<0.001	-0.390	-	<0.001	-0.309
NO_3+NO_2-N	+	<0.001	0.107	+	< 0.001	0.093	+	<0.001	0.085
TKN	-	<0.001	-0.375	-	<0.001	-0.356	-	<0.001	-0.270
Total P	+	0.014	0.013	+	<0.001	0.023	+	<0.001	0.033
SO_4	+	0.047	0.833	+	0.001	1.471	+	0.004	1.38
Turbidity	ns			ns			+	0.002	.400
TSS	ns			ns			ns		
Fecal coliforms	-	0.064	-233	-	<0.001	-1000	-	<0.001	-219
Cyanide	-	<0.001	-.0013	-	<0.001	-.0014	-	<0.001	-.0007
Phenol	+	<0.001	0.833	+	0.004	1.000	+	<0.001	1.000

NOTES:
DO = dissolved oxygen
NH_4-N = ammonia-nitrogen
NO_3+NO_2-N = nitrate and nitrite-nitrogen
TKN = total Kjeldahl nitrogen
P = phosphorus
SO_4 = sulphate
TSS = total suspended solids
ns = not significant
+ = increasing trend
- = decreasing trend

Secondary Contact standard at these stations, lower values still occur. As recently as 1993, 25 percent of the measurements at station M-6 were below the standard.

Decreasing trends in NH_4-N concentrations were found at all three Cal-Sag stations (figures H-2, I-2, and J-2). Decrease rates have exceeded 0.3 mg/L per year at all three stations.

Increasing trends in NO_3+NO_2-N were significant at all three stations (figures H-3, I-3, and J-3). Rates of increases have ranged from 0.085 mg/L per year at station M-9 to 0.107 mg/L per year at station M-7.

Significant downward trends in TKN (figures H-4, I-4, and J-4) also were found at all three stations. Decreases ranged from 0.27 mg/L per year at station M-9 to 0.375 mg/L per year at station M-7.

Increasing trends of total P (figures H-5, I-5 and J-5) were detected at all three stations. The increase rates ranged from 0.013 mg/L per year at station M-7 to 0.033 mg/L per year at station M-9.

Increasing trends in SO_4 concentrations also were found at all three stations (figures H-6, I-6, and J-6). The increases ranged from 0.833 mg/L per year at station M-6 to 1.471 mg/L per year at station M-8.

An increasing trend in turbidity was detected at station M-7 (figure H-7) only, where an increase of 0.40 NTU per year was found. No significant trends were detected at stations M-7 or M-8 (figures I-7 and J-7).

No significant trends in TSS concentrations were found at the three stations (figures H-8, I-8, and J-8).

Decreasing trends of fecal coliform densities were significant at all three stations. The decrease rate was the greatest at station M-8 (1000 colonies/100 mL per year) and densities at stations M-7 and M-9 decreased 223 and 219 colonies/100 mL per year, respectively. Box plots of the data (figures H-9, I-9, and J-9) show that densities were very low prior to the cessation of effluent chlorination in 1983, were high in the period prior to implementation of TARP in 1987, and have since decreased.

Decreasing trends of cyanide concentrations were found at all three stations. Box plots of the data for each station (figures H-10, I-10, and J-10) show a step-decrease coincident with TARP implementation in 1988. No samples collected since 1988 at stations M-7, M-8, or M-9 have exceeded the Secondary Contact standard for cyanide.

Increasing trends of phenol concentrations were statistically significant at all three stations. Examination of the box plots in figures H-11, I-11 and J-11 clearly shows that this result is due to increased concentrations during the mid-1980s. This period was followed by a step decrease in concentrations in 1988. No samples collected at any of the three stations contained phenol concentrations exceeding the Secondary Contact standard of 0.3 mg/L.

Chicago Sanitary and Ship Canal Downstream of the Cal-Sag Channel (Stations M-10 and I-11)

Trends were determined at two stations on the Chicago Sanitary and Ship Canal downstream of the Cal-Sag Channel. Station M-10 is located at the Stephens Street Bridge and station I-11, an IEPA sampling station, is located at Romeoville. Data were available for some variables (NO_3+NO_2-N and total P) at station I-11 from 1968 to 1995. Data for NH_4-N were available for 1971-1995. Turbidity and TSS data were available for the period beginning in 1974. An insufficient number of SO_4, phenol, cyanide, and fecal coliform observations were available to permit a trend analysis of these analytes.

Results of the seasonal Kendall test for these stations are given in table 8. Box plots are given in appendix K for station M-10 and appendix L for station I-11.

Significant upward trends were detected for DO at both stations. The DO increased at a rate of 0.167 mg/L per year at station M-10 and 0.152 mg/L per year at station I-11. As shown in figures K-1 and L-1, the occurrence of samples with DO concentrations below the Secondary Contact standard of 4.0 mg/L is much lower now than it was in the 1970s or 1980s.

Downward trends were significant at both stations for NH_4-N (figures K-2 and L-2). A decrease of 0.190 mg/L per year occurred at station M-10, while the decrease at station I-11 was 0.150 mg/L per year. The plot of NH_4-N at station I-11 (figure L-2) shows the substantial improvements in water qualities that have occurred since the early 1970s. The median concentration from 1970-1975 was 6.6 mg/L, and from 1990-1995 it was 1.14 mg/L.

Increasing concentrations of NO_3+NO_2-N data were found at both stations M-10 (figure K-3) and I-11 (figure L-3). At station M-10 a rate of change of 0.040 mg/L per year was found. The rate of change at station I-11 was 0.115 mg/L per year over the 28-year period that data have been collected at the station.

Downward trends also were significant for TKN at station M-10 (figures K-4). The TKN decreased at a rate of 0.176 per year.

A significant upward trend in total P concentrations was detected for station I-11 only (figure L-4). No significant trend was found at station M-10 (figure K-5).

An upward trend was detected at station M-10 (figure K-6) for SO_4 concentration, with a rate of increase of 1.183 mg/L per year. No SO_4 concentrations were available for station I-11.

Table 8. Results of the Seasonal Kendall Trend Test and Slope Estimator for Stations M-10 (Chicago Sanitary and Ship Canal at Stephens St.), 1974-1995, and I-11 (Chicago Sanitary and Ship Canal at Romeoville), 1967-1995

	M-10			*I-11*		
Parameter	*Direction*	*p-value*	*Slope*	*Direction*	*p-value*	*Slope*
DO	+	<0.001	0.167	+	<0.001	0.152
NH_4-N	-	<0.001	-0.190	-	<0.001	-0.150
NO_3+NO_2-N	+	0.067	0.040	+	<0.001	0.115
TKN	-	<0.001	-0.176	NA		
Total P	ns			+	<0.001	0.013
SO_4	+	<0.001	1.183	NA		
Turbidity	ns			ns		
TSS	ns			ns		
Fecal coliforms	-	0.002	-126	NA		
Cyanide	-	<0.001	0.0006	NA		
Phenol	-	0.004	-0.571	NA		

NOTES:
DO = dissolved oxygen
NH_4-N = ammonia-nitrogen
NO_3+NO_2-N = nitrate and nitrite-nitrogen
TKN = total Kjeldahl nitrogen
P = phosphorus
SO_4 = sulphate
TSS = total suspended solids
ns = not significant
NA = not applicable
+ = increasing trend
- = decreasing trend

No significant trends were detected at either station for turbidity or TSS. A downward trend of cyanide concentration was significant at station M-10. Cyanide data were not available for station I-11. The cyanide concentrations decreased at rates of 0.0006 mg/L per year. No samples collected from this station exceeded the Secondary Contact standard of 0.1 mg/L.

An increasing trend in phenol concentrations was detected at station M-10. No samples from this station have exceeded the Secondary Contact standard of 300 :g/L.

Illinois River at Marseilles (Station G-12)

The only parameters available at station G-12 were NH_4-N, total P, and TSS. The period of record for this station was 1975-1995 for total P and TSS, and from 1978-1995 for NH_4-N. Trend analysis results are given in table 9. Box plots are given in appendix M.

A statistically significant downward trend in NH_4-N was detected. The NH_4-N concentrations decreased at a rate of -0.052 mg/L per year (figure M-1).

A significant downward trend in total P concentration was detected (figure M-2). The magnitude of the trend was -0.005 mg/L per year.

A statistically significant downward trend in TSS concentrations was detected with a decrease of 3.941 mg/L per year (figure M-3).

Trends of turbidity and fecal coliform densities were not significant.

Illinois River at Peoria (Station S-13)

The only parameters available at this station were DO, NH_4-N, NO_3+NO_2-N, phosphate (PO_4-P), turbidity, and TSS. As a substitute for total P, which was not available at this station, PO_4-P was used. The period of record for all parameters was 1965-1995. Trend analysis results are given in table 7. Box plots are given in appendix N.

A significant upward trend was detected for DO at station S-13. The DO concentrations increased at a rate of 0.049 mg/L per year (figure N-1). This amounts to only 0.6 percent of the long-term (1965-1995) median concentration. Dissolved oxygen concentrations are now consistently above the IPCB standard of 5.0 mg/L.

The improvements in NH_4-N concentrations are more impressive (figure N-2). The significant downward trend amounted to a net decrease of 0.200 mg/L per year. This annual change represents 7.7 percent of the 1965-1995 median.

No significant trend was found for NO_3+NO_2-N at this station (figure N-3). A significant downward trend of PO_4-P was found with an average decrease of 0.010 mg/L per year (figure N-4).

A downward trend of TSS concentrations was also found at this station (figure N-5). The annual decrease averaged 1.556 mg/L per year. An upward trend of turbidity was detected, with an overall increase of 1.233 NTU per year.

Kendall Trend Test Results for All Sites

Table 10 summarizes the results of the Kendall Seasonal Trend test for all sites. These results are based on the data given in tables 4-9.

Table 9. Results of the Seasonal Kendall Trend Test and Slope Estimator for Stations G-12 (Illinois River at Marseilles) and S-13 (Illinois River at Peoria), 1965-1995

Parameter	*G-12*			*S-13*		
	Direction	*p-value*	*Slope*	*Direction*	*p-value*	*Slope*
DO	NA			+	<0.001	0.049
NH_4-N	-	<0.001	-0.052	-	<0.001	-0.020
NO_3+NO_2-N						
TKN	NA			NA		
Total P	-	<0.001	-0.005	-	<0.001	-0.010
SO_4	NA			NA		
Turbidity	ns			+	<0.001	1.233
TSS	-	<0.001	-3.941	-	<0.001	-1.556
Fecal coliforms	ns			NA		
Cyanide	NA			NA		
Phenol	NA			NA		

NOTES:
DO = dissolved oxygen
NH_4-N = ammonia-nitrogen
NO_3+NO_2-N = nitrate and nitrite-nitrogen
TKN = total Kjeldahl nitrogen
P = phosphorus
SO_4 = sulphate
TSS = total suspended solids
ns = not significant
NA = not applicable
+ = increasing trend
- = decreasing trend

Table 10. Summary of trends detected with the seasonal Kendall trend test

Parameter	*M-0*	*M-1*	*M-2*	*M-3*	*M-4*	*M-5*	*M-6*	*M-7*	*M-8*	*M-9*	*M-10*	*I-11*	*G-12*	*S-13*
DO	ns	+	+	+	+	+	+	+	+	+	+	+		+
NH_4-N	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NO_3+NO_2-N	+	+	ns	+	+	+	ns	+	+	+	+	+		ns
TKN	-	-	-	-	-	-	-	-	-	-	-			
Total P	-	-	-	-	-	-	-	+	+	+	+	+	-	-
SO_4	ns	+	+	+	+	ns	ns	+	+	+	+			
Turbidity	+	ns	+	+	+	ns	ns	ns	+	+	ns	ns		+
TSS	-	-	ns	ns	-	-	-	ns	ns	ns	ns	ns	-	-
Fecal Coliforms	-	+	-	-	-	ns	ns	-	-	-	-			
Cyanide	-	-	-	-	-	-	-	-	-	-	-			
Phenol	-	-	-	-	-	-	-	-	-	-	-			

NOTES :
DO = dissolved oxygen
NH_4-N = ammonia-nitrogen
NO_3+NO_2-N = nitrate and nitrite-nitrogen
TKN = total Kjeldahl nitrogen
P = phosphorus
SO_4 = sulphate
TSS = total suspended solids
ns = not significant
+ = increasing trend
- = decreasing trend

Conclusions

Positive trends in DO were found throughout the Illinois Waterway, with the exception of station M-1, at which no trend was detected. Given the importance of DO in the support of aquatic life, this is a very positive indication of the recovery of the waterway. Supplemental aeration was implemented on the Cal-Sag Channel in the form of SEPA stations. Dissolved oxygen concentrations below the water quality standards are no longer a common occurrence along the waterway.

Also encouraging are the decreases in NH_4-N, which is toxic to aquatic life in its un-ionized form. Significant decreases in NH_4-N concentrations occurred at each of the 14 stations included in this study.

Statistically significant increases in NO_3+NO_2-N concentrations were detected at nine stations in the Chicago-area waterways. No significant changes were found at two additional stations. At each station with an increasing trend, an accompanying significant decrease in NH_4-N was detected. This indicates that the increased NO_3+NO_2-N concentrations are the result of the oxidation of NH_4-N. At the Illinois River at Marseilles (station G-12), a decreasing trend in NO_3+NO_2-N concentrations was accompanied by a decreasing trend in NH_4-N. Since TKN values were not available for these stations, it is inconclusive whether these decreasing trends are the result of an overall decrease in nitrogen.

No significant trend for NO_3+NO_2-N was found at Peoria (station S-13).

Downward trends in TKN occurred at the 11 stations for which TKN data were available.

Results for total P were variable in the Chicago-area waterways. Stations located on the North Shore Channel, the Chicago River, and the Chicago Sanitary and Ship Canal above the Cal-Sag Channel experienced downward trends or no change. Concentrations

increased at stations on the Cal-Sag Channel and the Chicago Sanitary and Ship Canal below the Cal-Sag Channel. Most importantly, however, decreases were detected at both Marseilles and Peoria.

Increasing SO_4 concentrations occurred throughout Chicago-area waterways. The cause of this increase is not clear.

Turbidity values have shown no change or increases throughout the waterway. When increases have occurred, the changes have been relatively small. Many processes, including nonpoint runoff, resuspension of bottom sediments, and algal growth can affect turbidity. It is not clear what the contributing factors are at the locations at which turbidity values have increased.

Overall, TSS concentrations remain unchanged at most locations in this study. The only exception is at Marseilles and Peoria, where slight decreases have occurred.

Overall, fecal coliform densities decreased at most stations. Increased coliform levels occurred at some stations in the early 1980s when chlorination of wastewater effluents ceased. However, a significant decrease occurred with the implementation of the TARP in 1984.

Decreasing trends of cyanide and phenol concentrations occurred throughout the waterway. The likely causes of such improvements are the TARP and improvements in waste treatment.

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Appendix A. Box Plots for Station M-0, North Shore Channel at Touhy Ave.

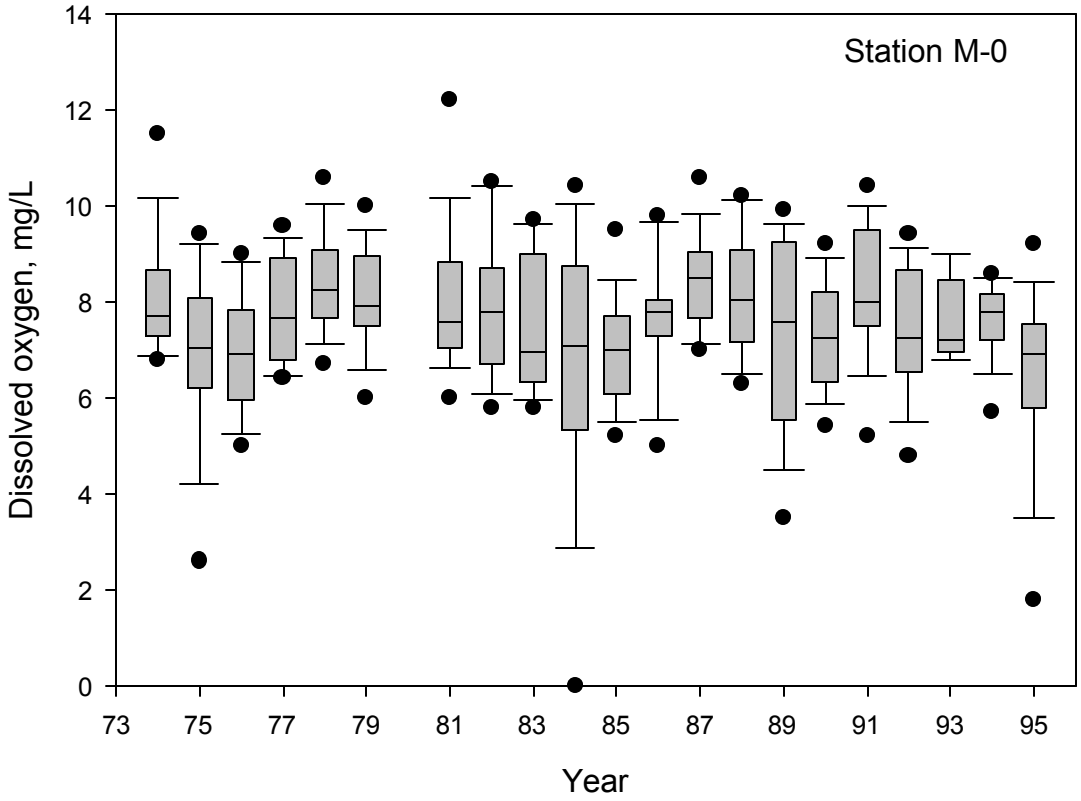

Figure A-1. Dissolved Oxygen (DO) at Touhy Ave. (M-0) in the North Shore Channel, 1974-1995. Data from MWRDGC.

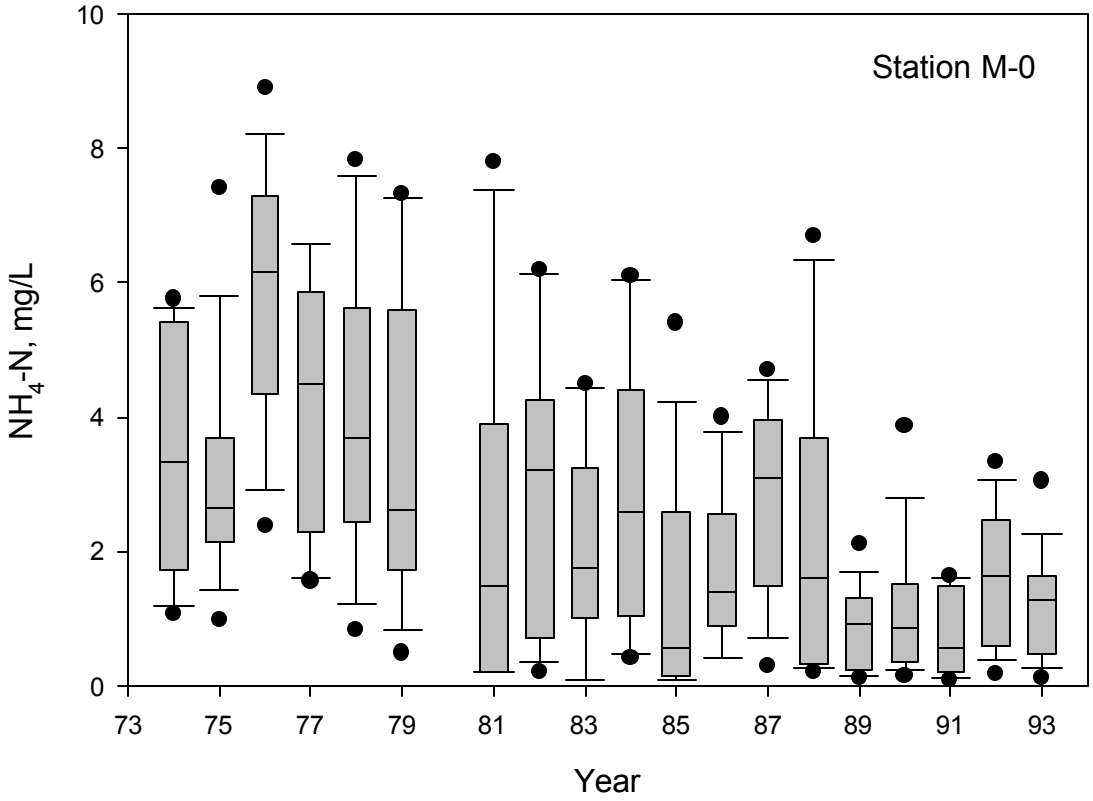

Figure A-2. Ammonia-Nitrogen (NH_4-N) at Touhy Ave. (M-0) in the North Shore Channel, 1974-1993. Data from MWRDGC.

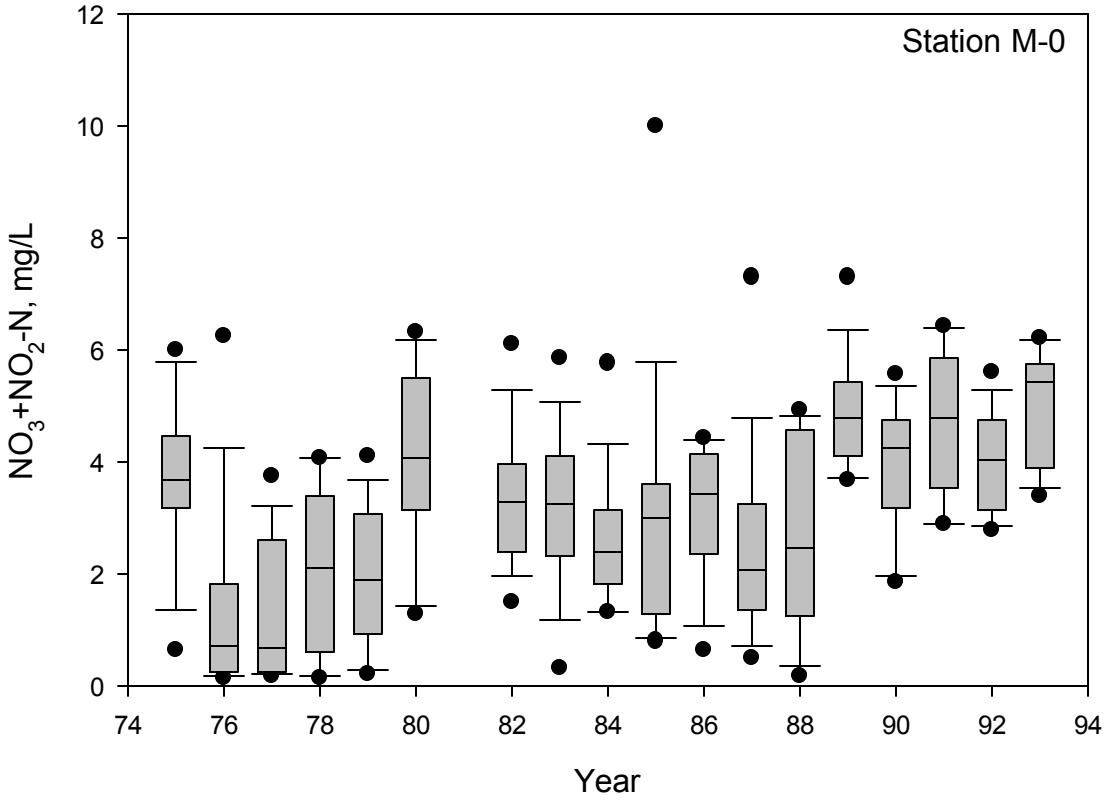

Figure A-3. Nitrate and Nitrite-Nitrogen (NO_3+NO_2-N) at Touhy Ave. (M-0) in the North Shore Channel, 1975-1993. Data from MWRDGC.

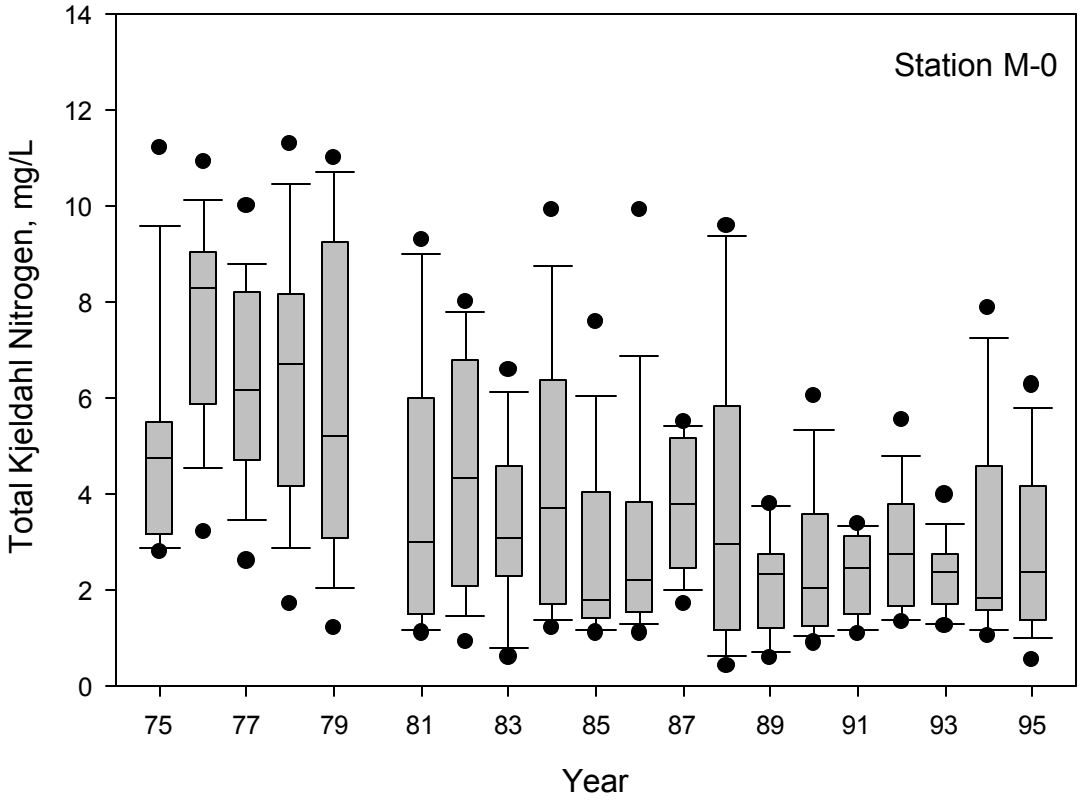

Figure A-4. Total Kjeldahl Nitrogen (TKN) at Touhy Ave. (M-0) in the North Shore Channel, 1975-1995. Data from MWRDGC.

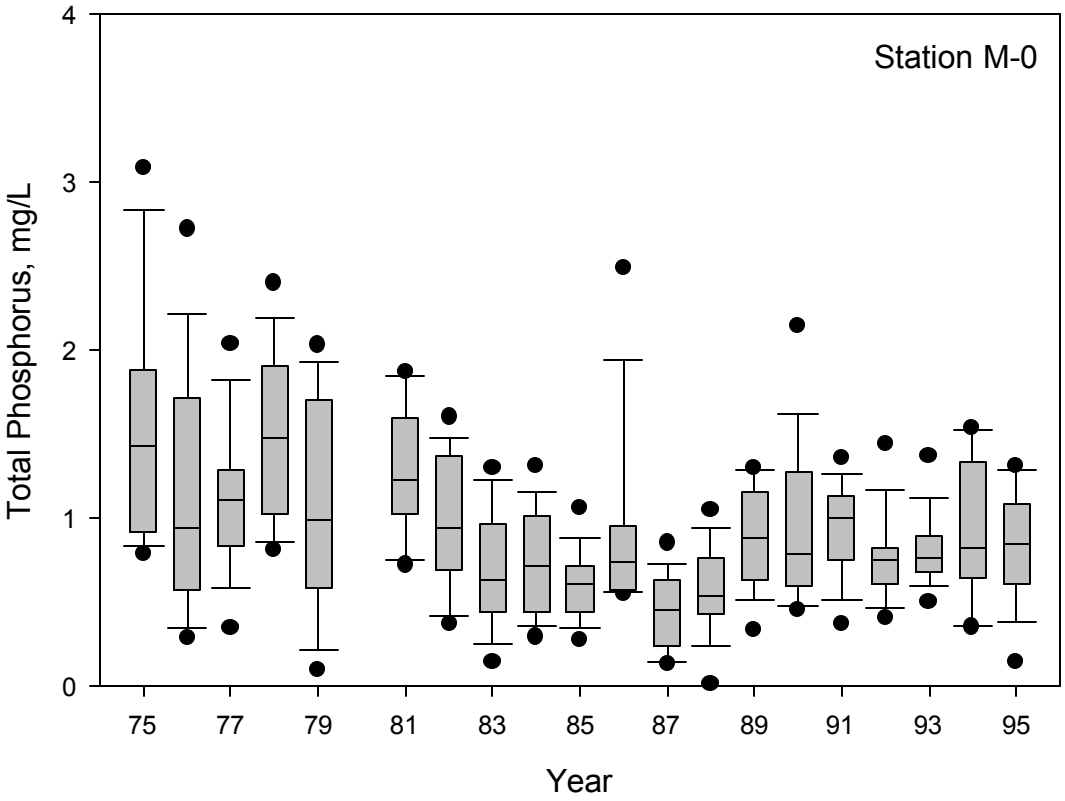

Figure A-5. Total Phosphorus (P) at Touhy Ave. (M-0) in the North Shore Channel, 1975-1993. Data from MWRDGC.

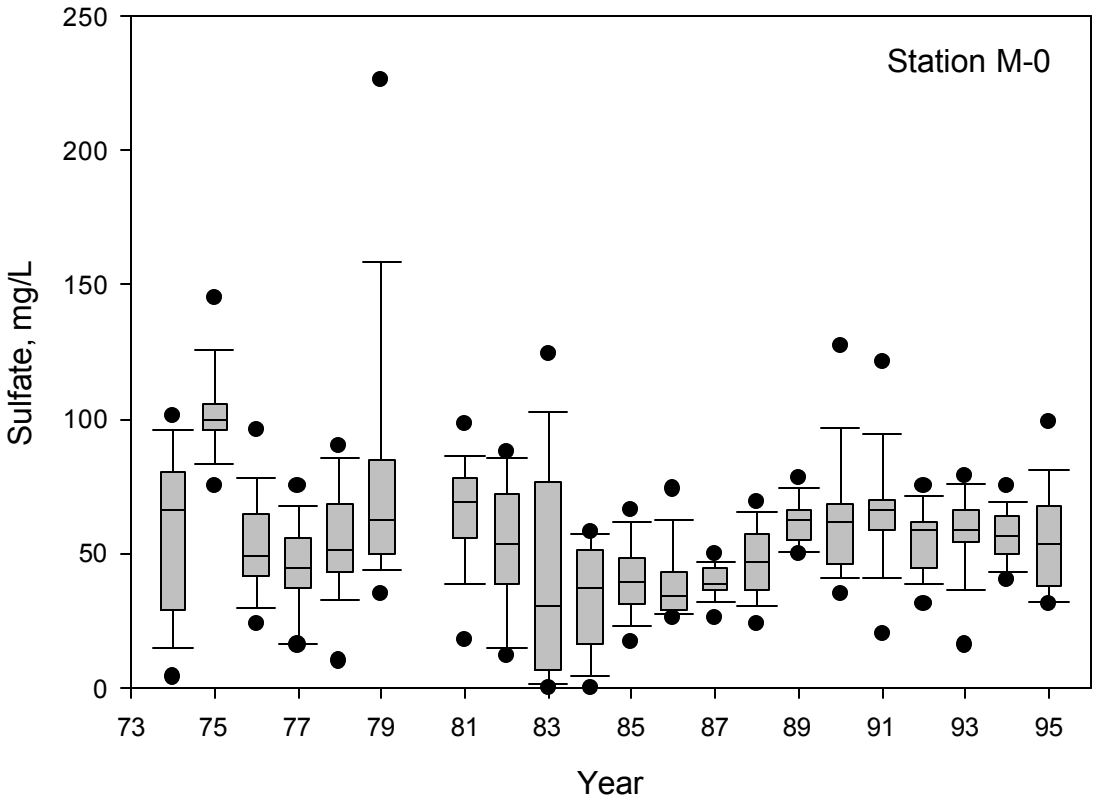

Figure A-6. Sulfate (SO_4) at Touhy Ave. (M-0) in the North Shore Channel, 1974-1995. Data from MWRDGC.

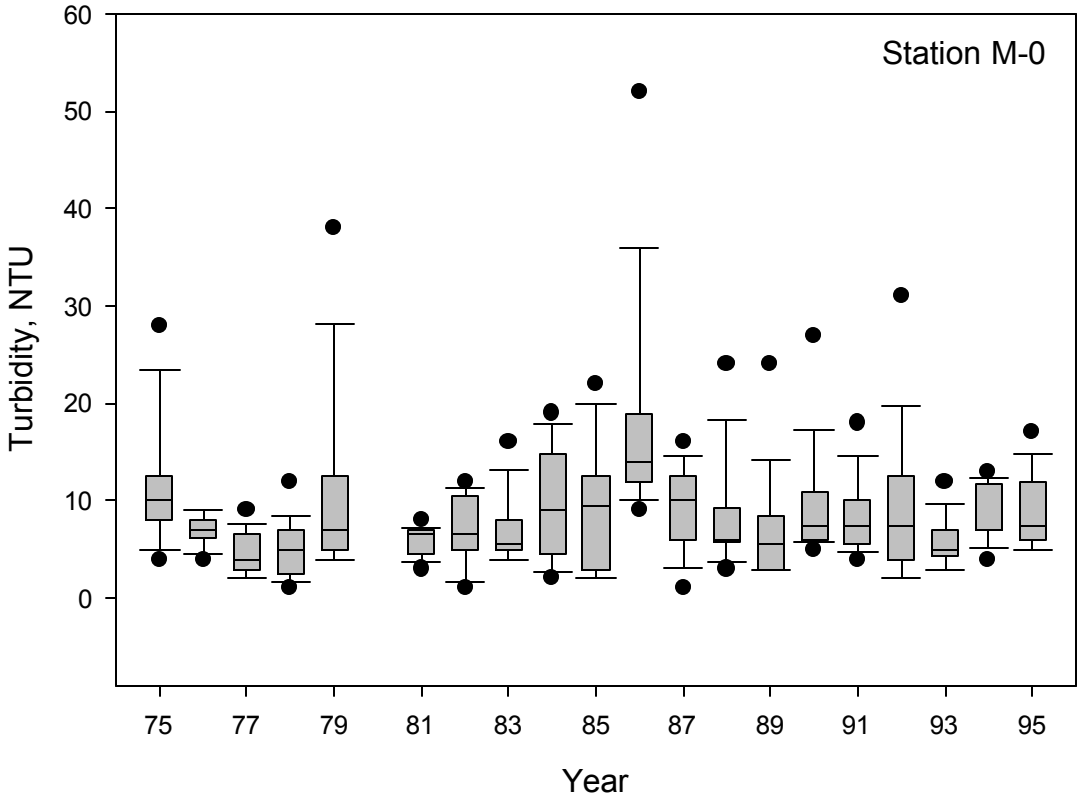

Figure A-7. Turbidity at Touhy Ave. (M-0) in the North Shore Channel, 1975-1993. Data from MWRDGC.

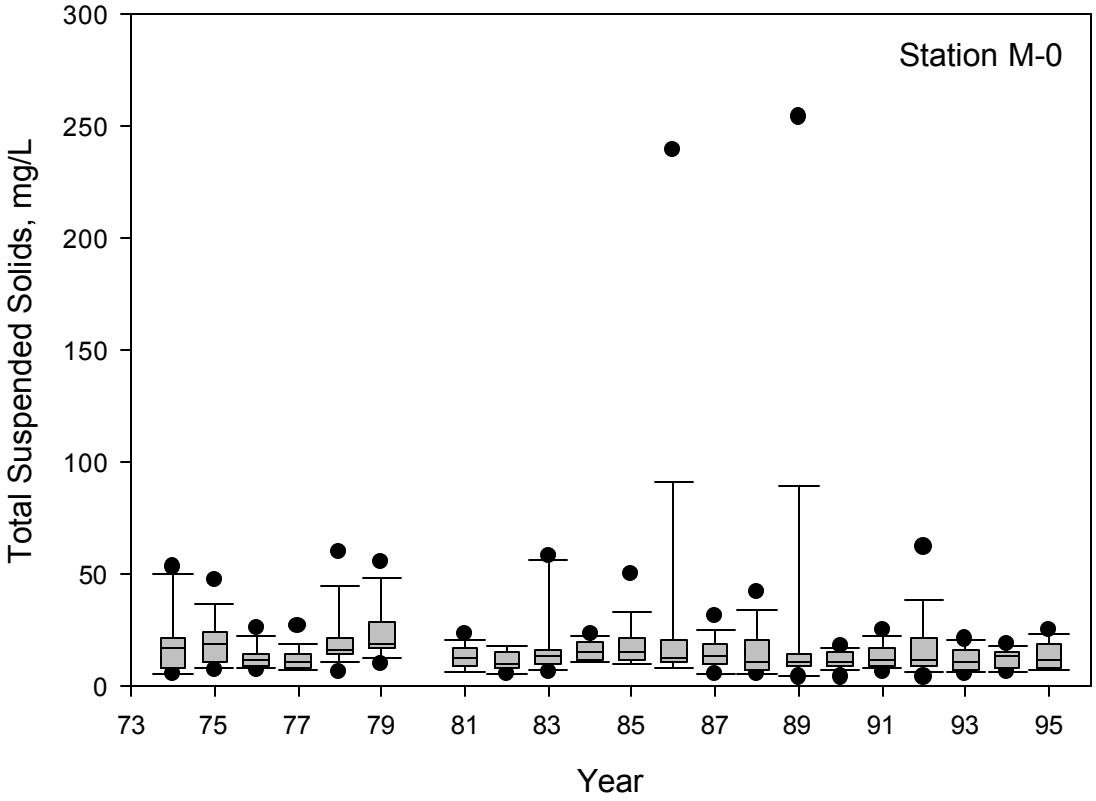

Figure A-8. Total Suspended Solids (TSS) at Touhy Ave. (M-0) in the North Shore Channel, 1974-1995. Data from MWRDGC.

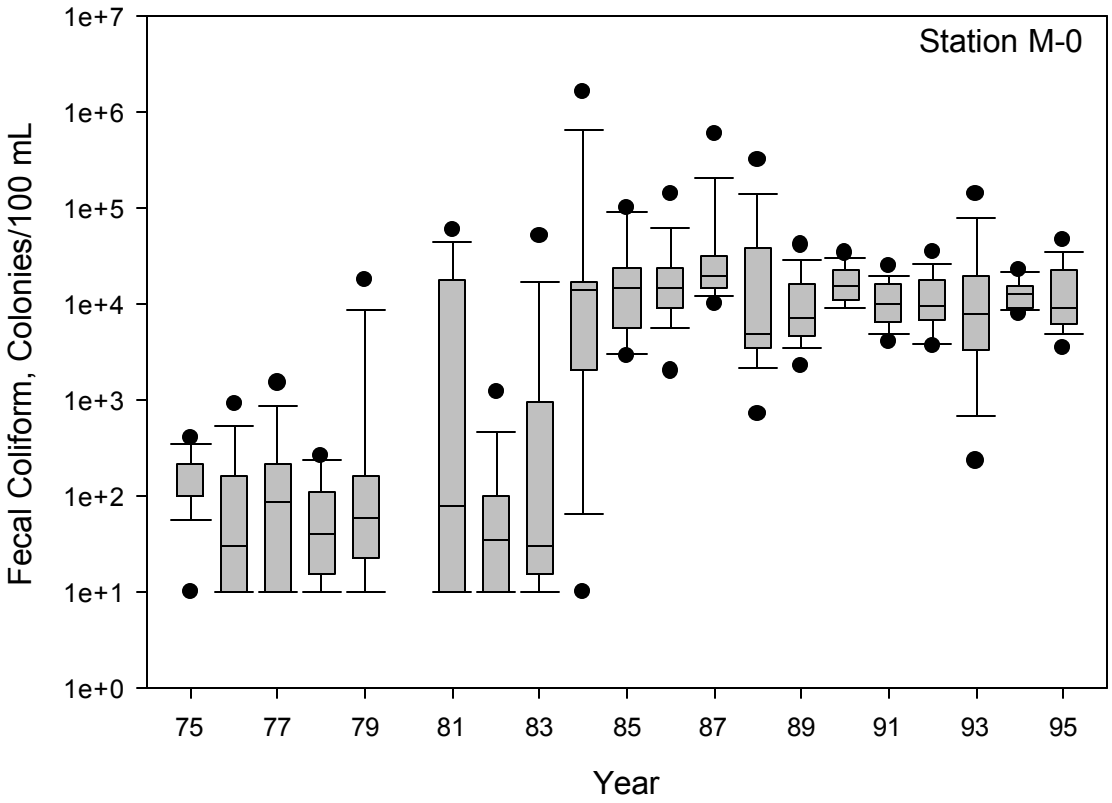

Figure A-9. Fecal Coliform Density at Touhy Ave. (M-0) in the North Shore Channel, 1975-1993. Data from MWRDGC.

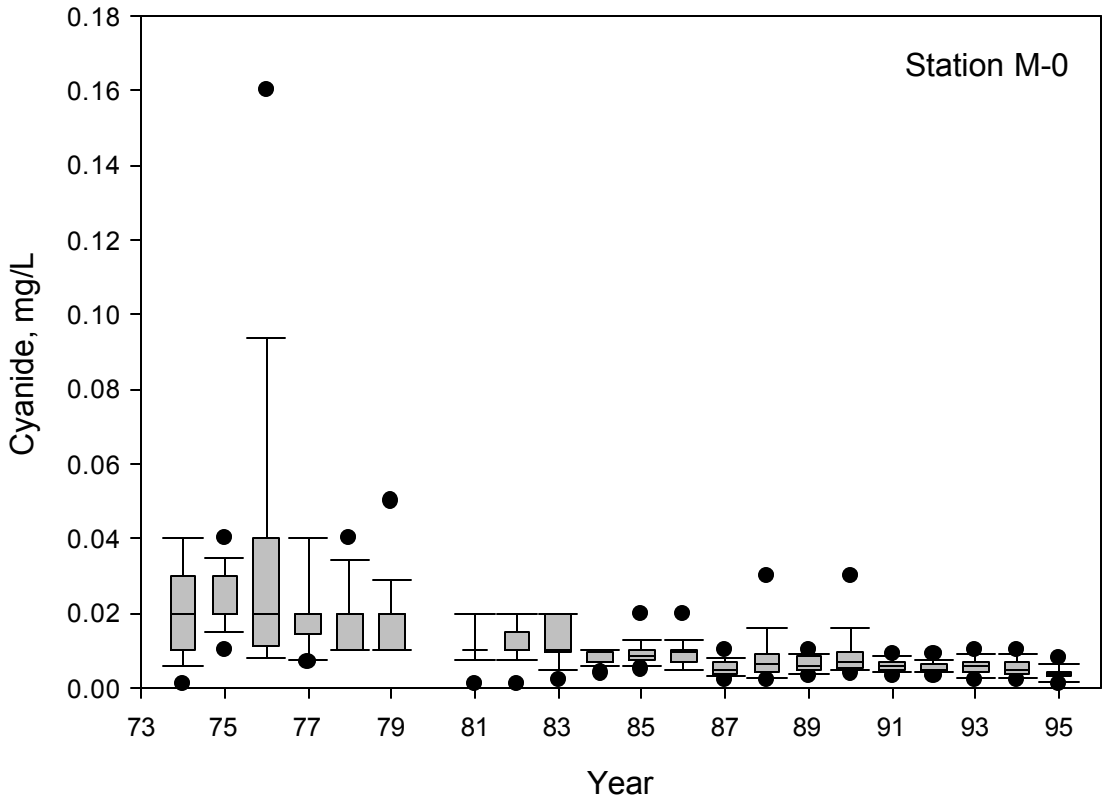

Figure A-10. Cyanide at Touhy Ave. (M-0) in the North Shore Channel, 1974-1993. Data from MWRDGC.

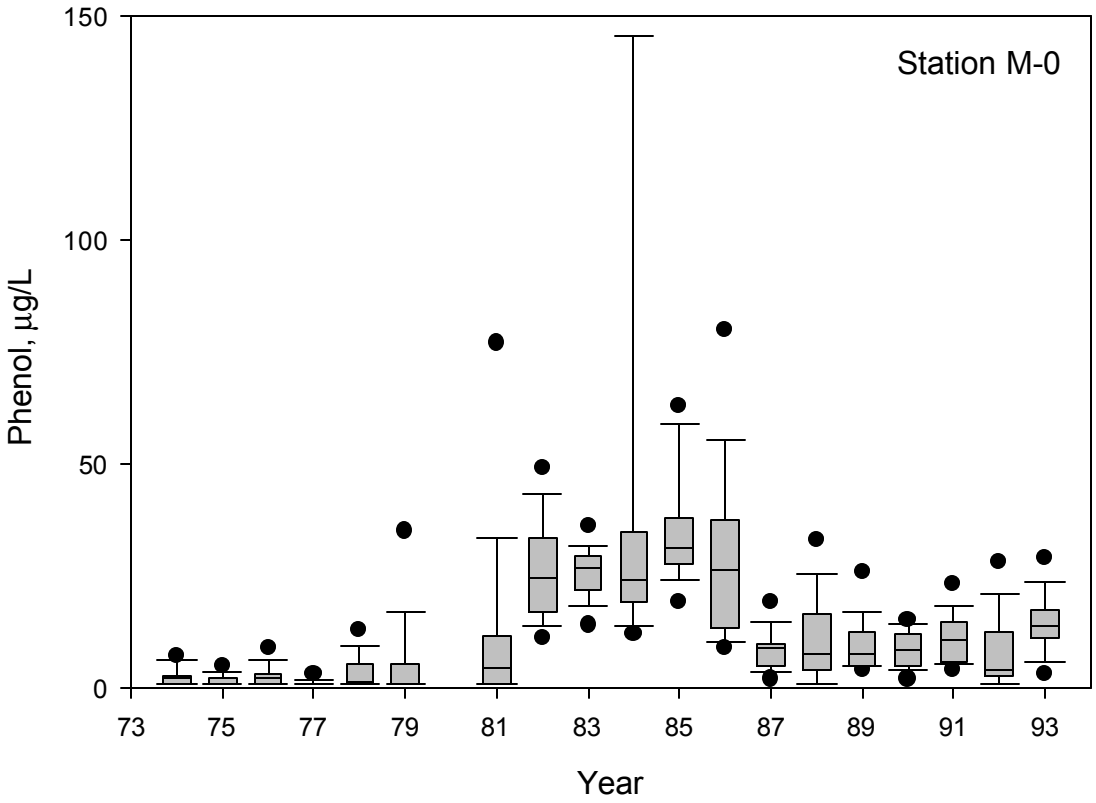

Figure A-11. Phenol at Touhy Ave. (M-0) in the North Shore Channel, 1974-1993. Data from MWRDGC.

Appendix B. Box Plots for Station M-1,
North Branch Chicago River at Grand Ave.

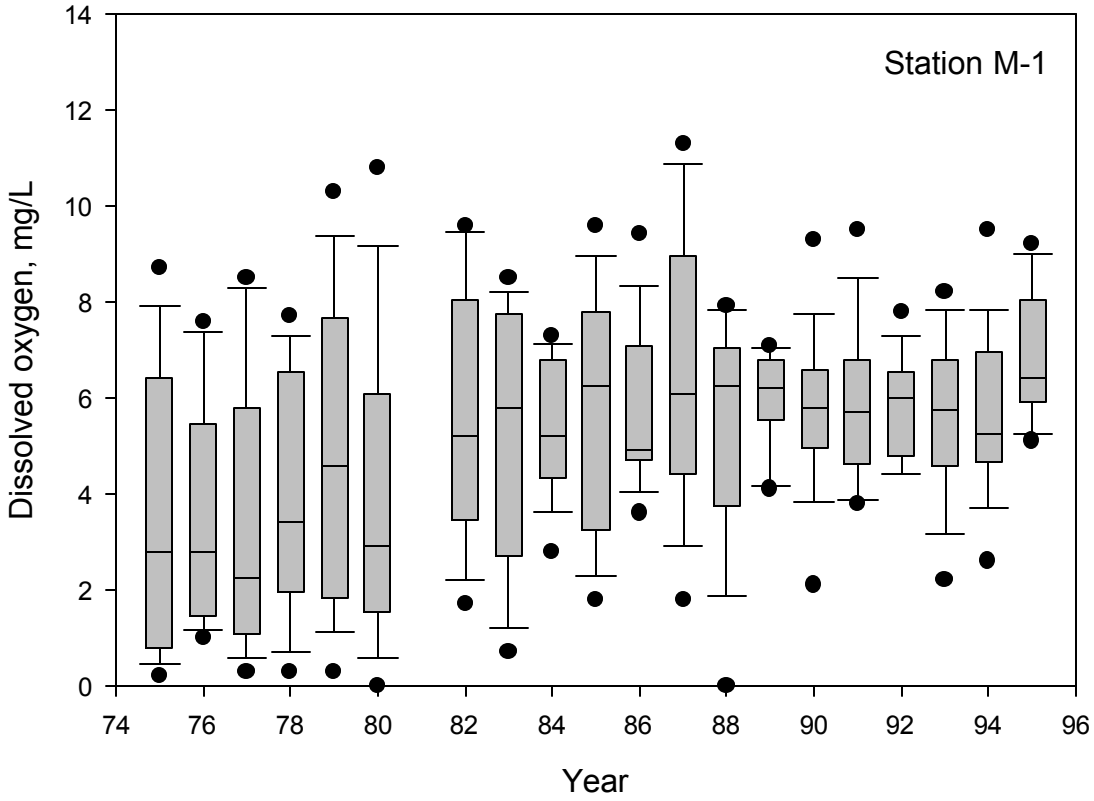

Figure B-1. Dissolved Oxygen (DO) at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1995. Data from MWRDGC.

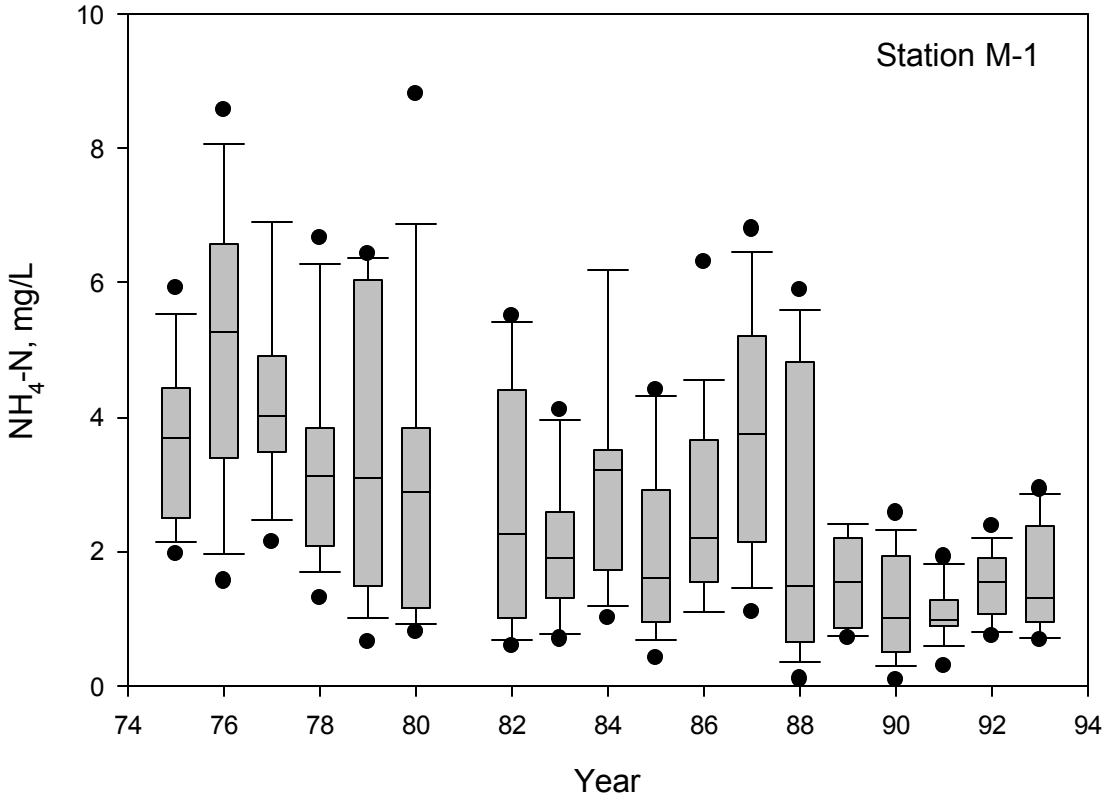

Figure B-2. Ammonia-Nitrogen (NH_4-N) at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1993. Data from MWRDGC.

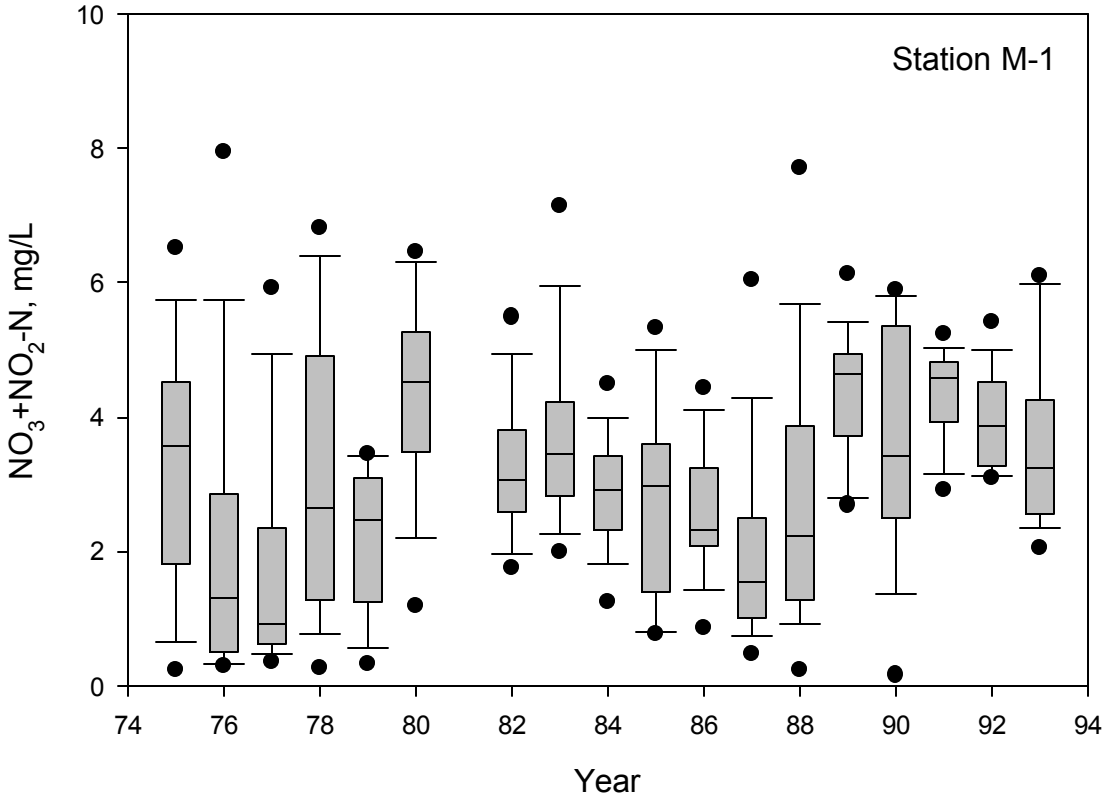

Figure B-3. Nitrate and Nitrite-Nitrogen (NO_3+NO_2-N) at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1993. Data from MWRDGC.

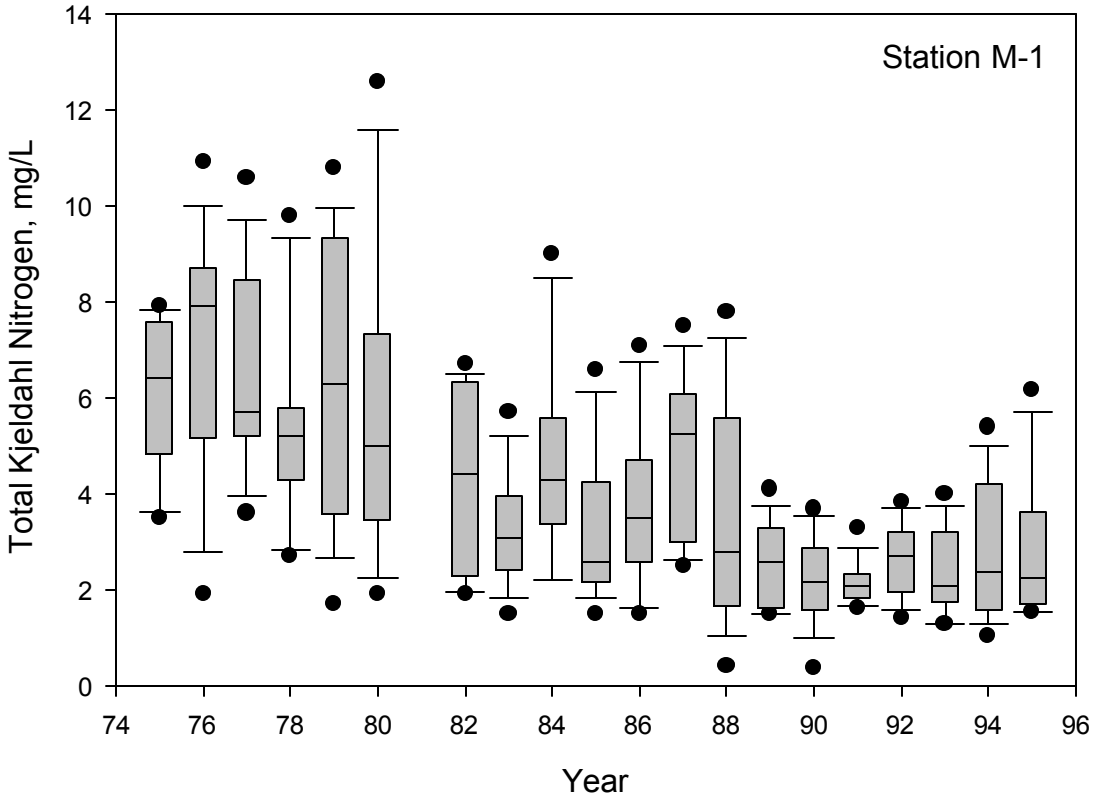

Figure B-4. Total Kjeldahl Nitrogen (TKN) at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1995. Data from MWRDGC.

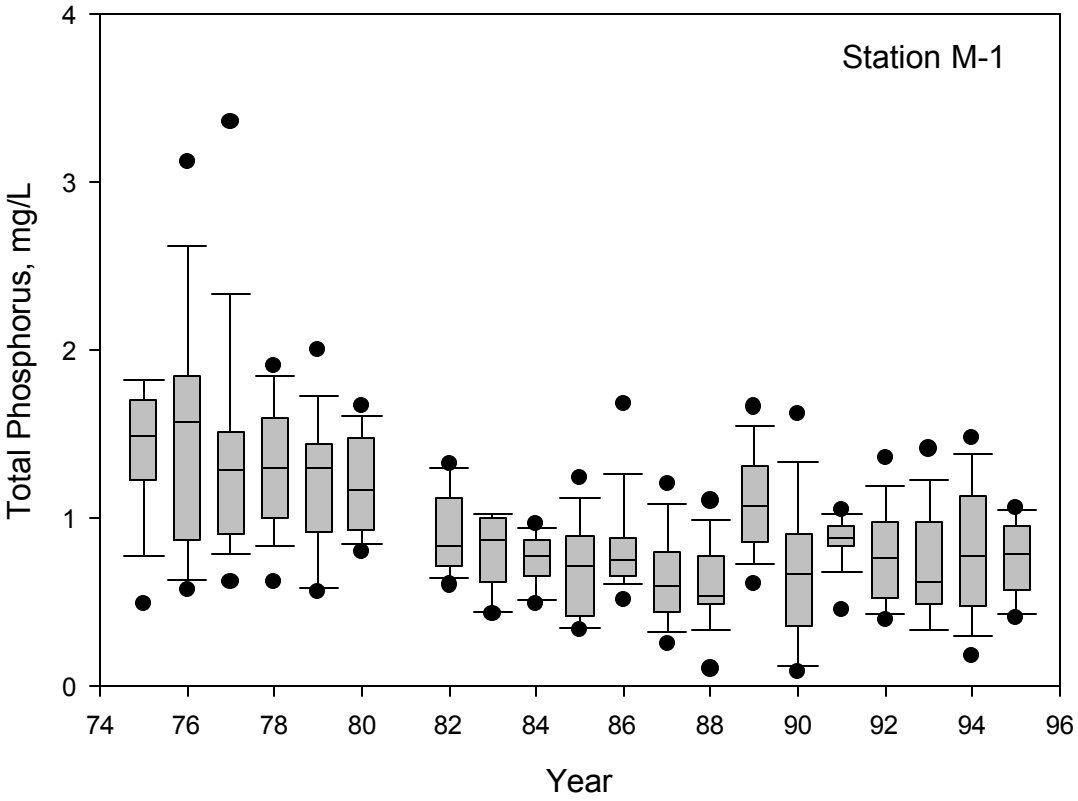

Figure B-5. Total Phosphorus (P) at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1995. Data from MWRDGC.

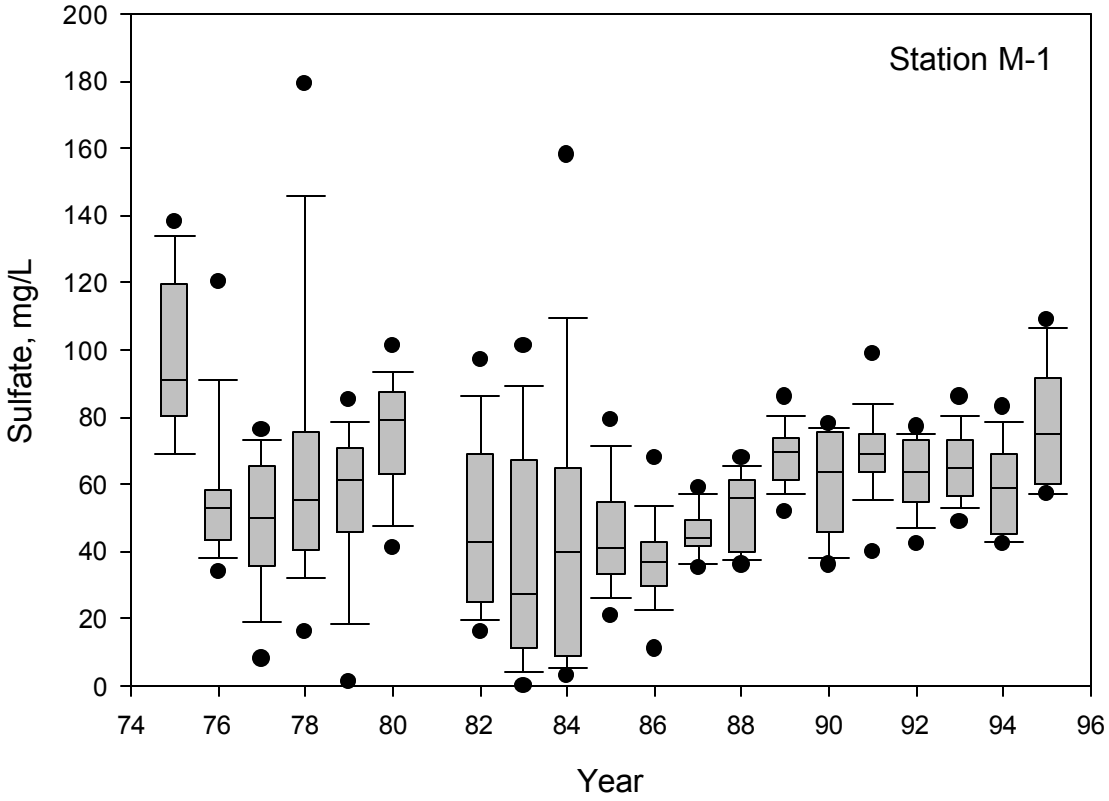

Figure B-6. Sulfate (SO_4) at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1995. Data from MWRDGC.

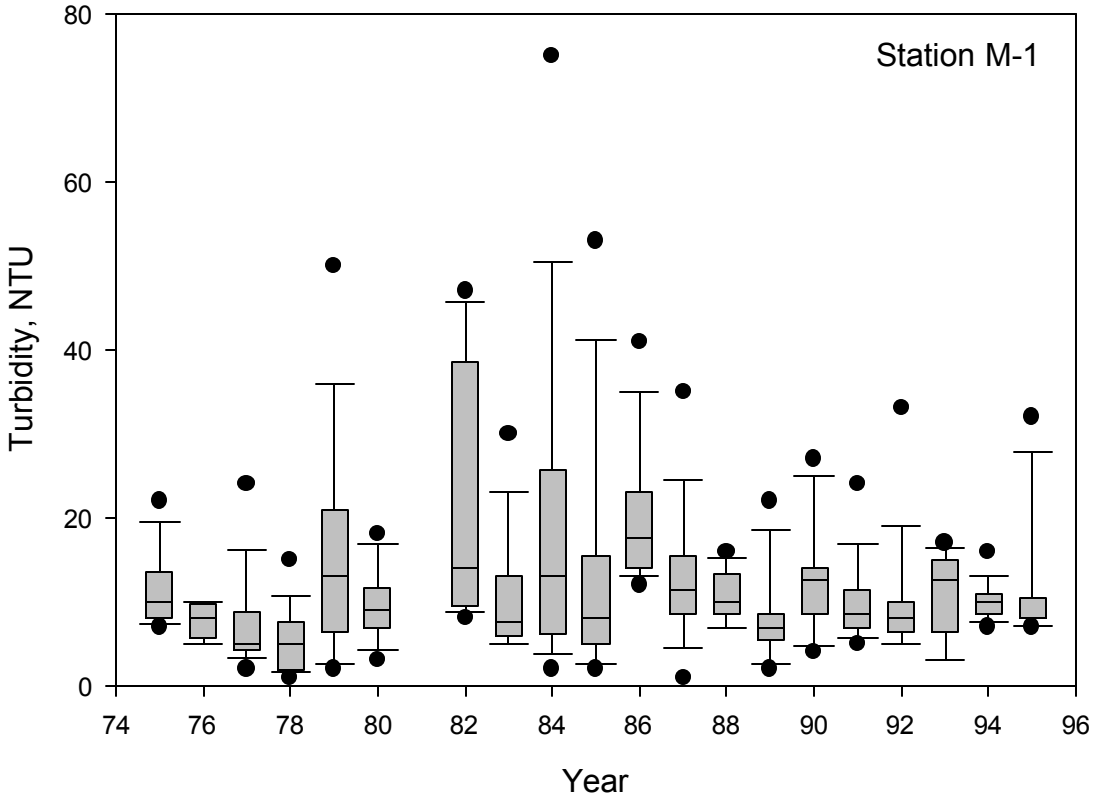

Figure B-7. Turbidity at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1995. Data from MWRDGC.

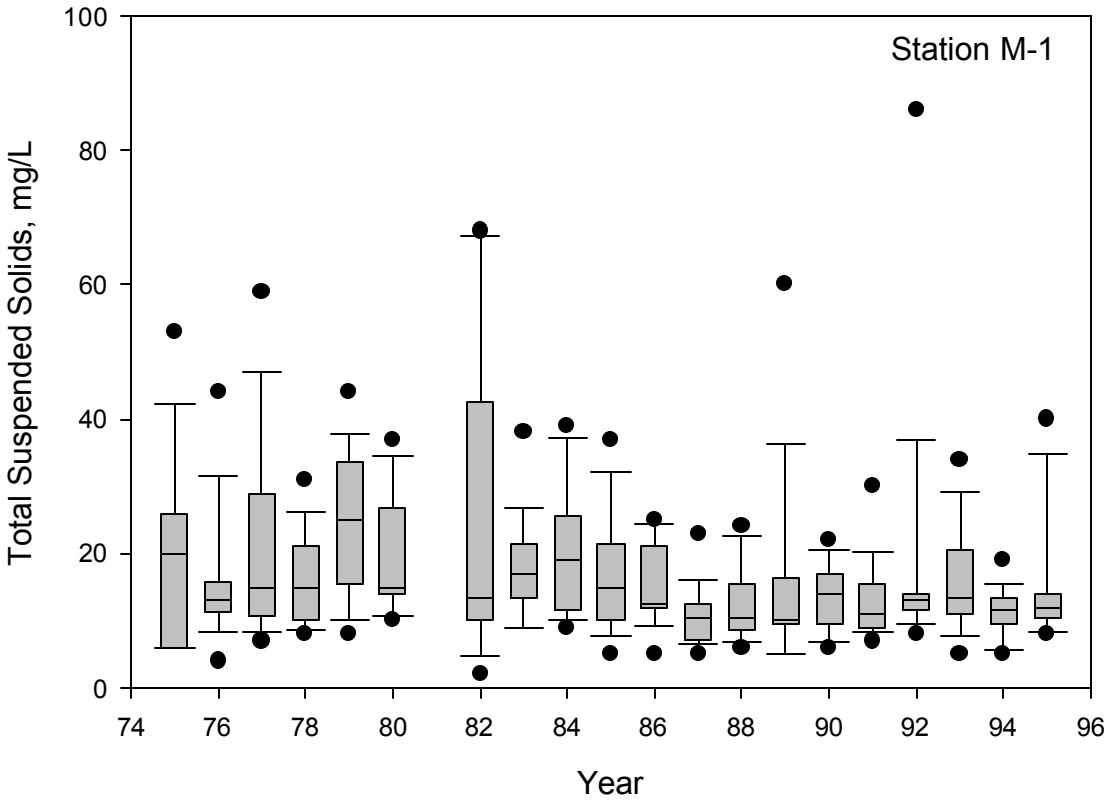

Figure B-8. Total Suspended Solids at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1995. Data from MWRDGC.

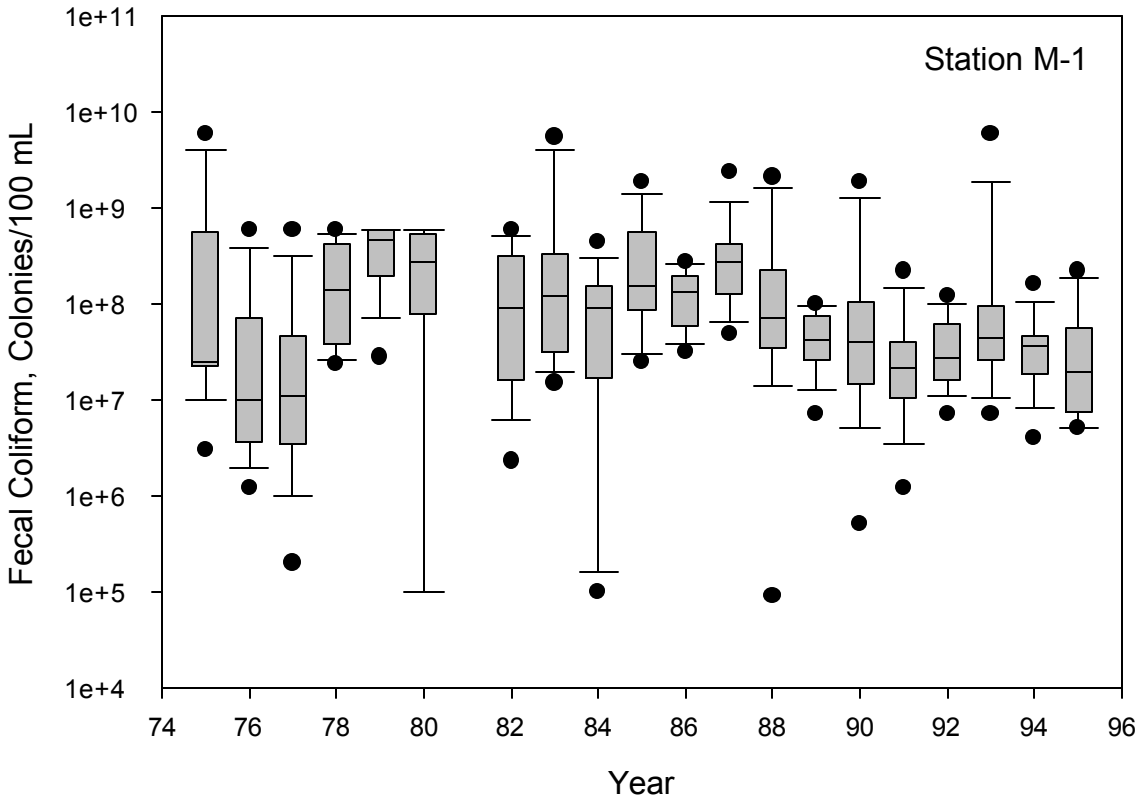

Figure B-9. Fecal Coliform Density at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1995. Data from MWRDGC.

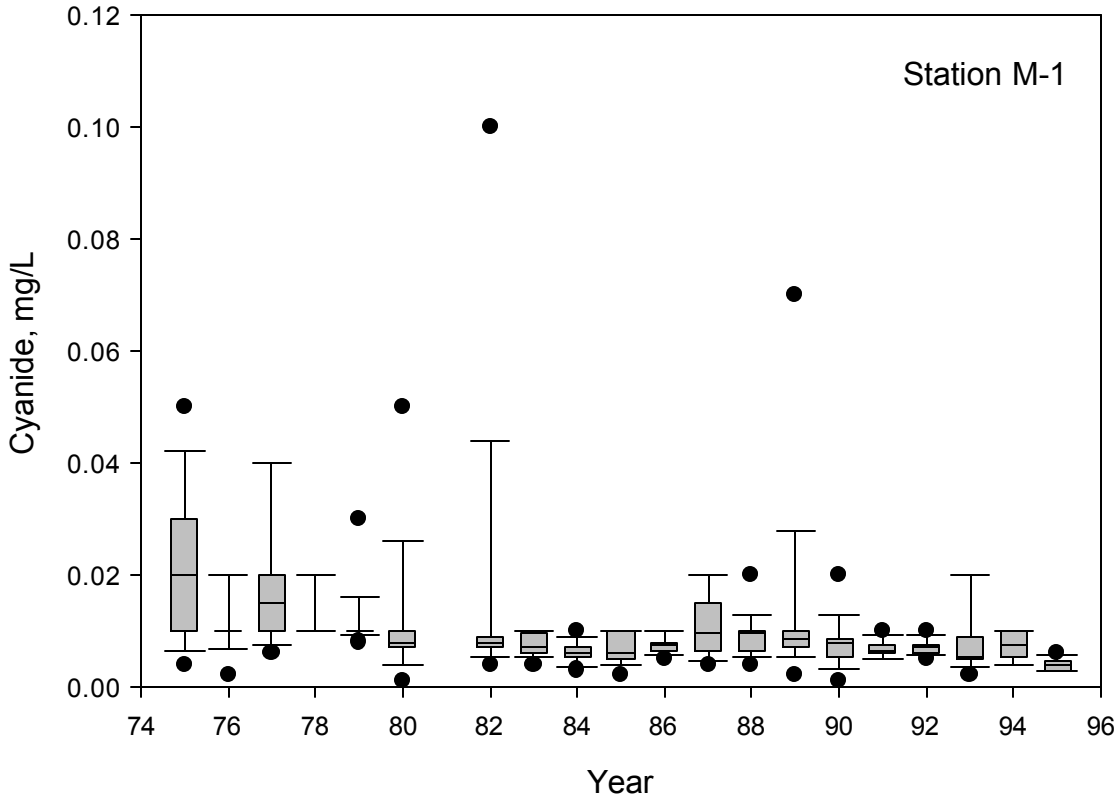

Figure B-10. Cyanide at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1995. Data from MWRDGC.

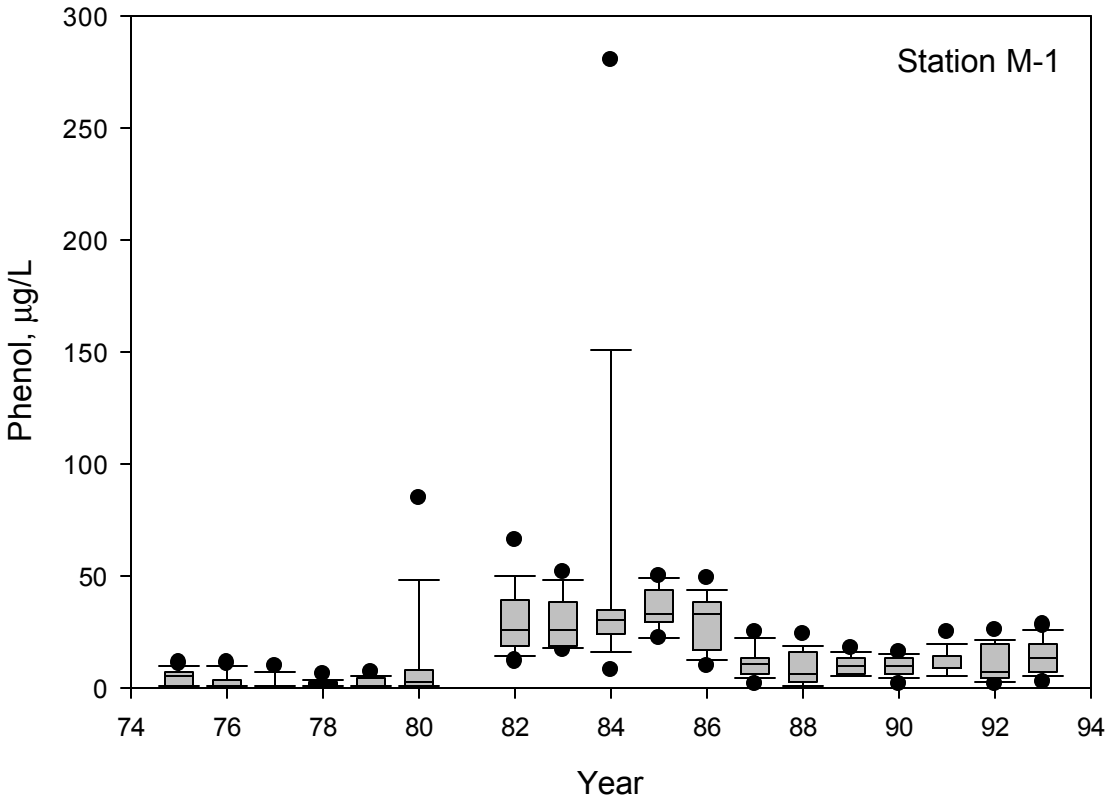

Figure B-11. Phenol at Grand Ave. (M-1) in the North Branch Chicago River, 1975-1993. Data from MWRDGC.

Appendix C. Box Plots for Station M-2,
South Branch Chicago River at Madison St.

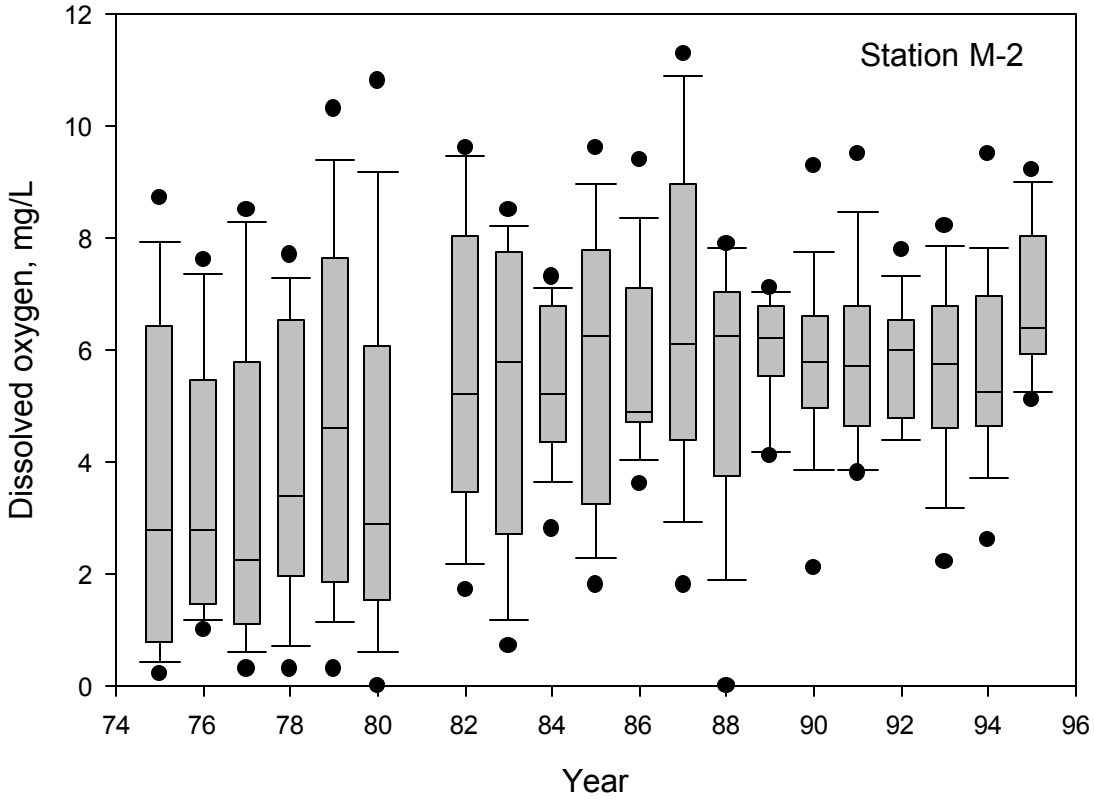

Figure C-1. Dissolved Oxygen (DO) at Madison St. (M-2) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

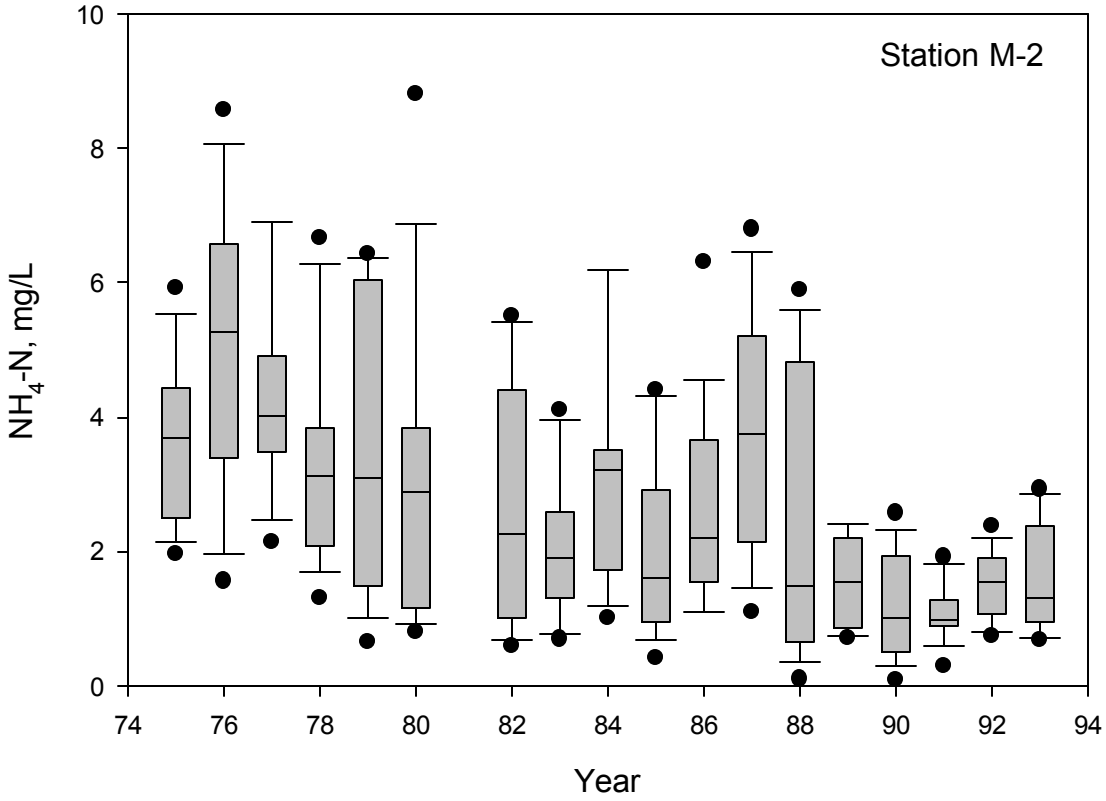

Figure C-2. Ammonia-Nitrogen (NH_4-N) at Madison St. (M-2) in the South Branch Chicago River, 1975-1993. Data from MWRDGC.

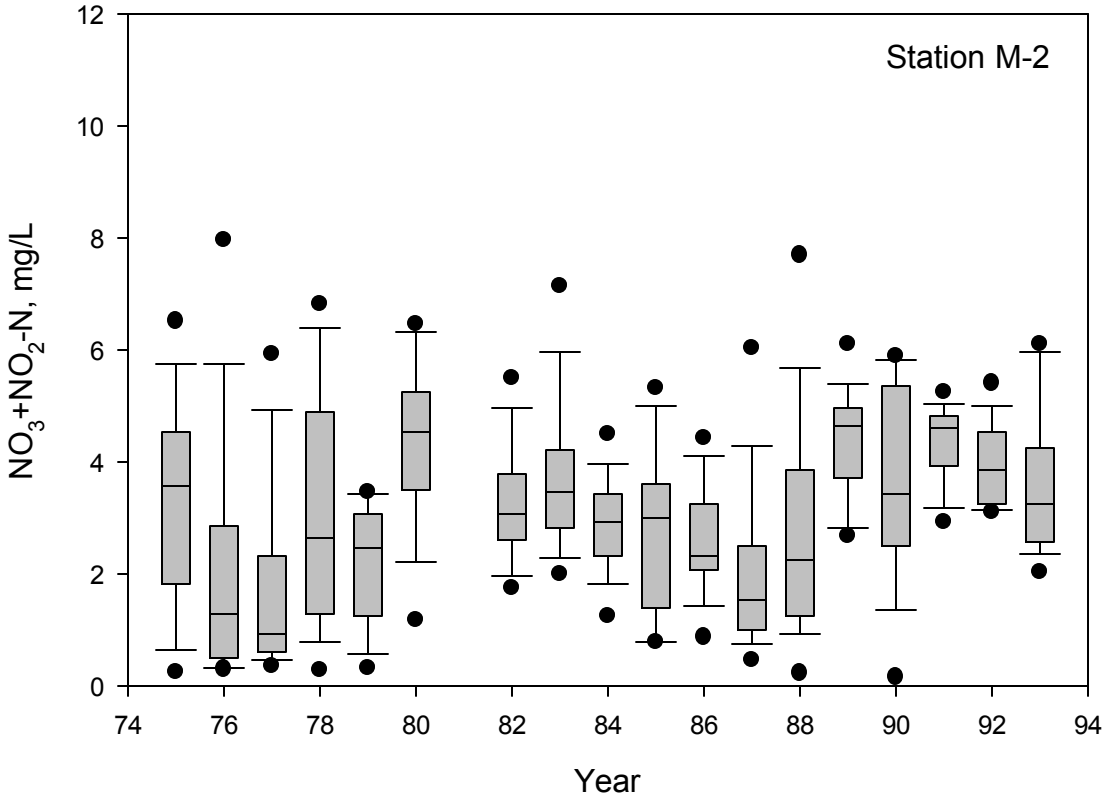

Figure C-3. Nitrate and Nitrite-Nitrogen (NO_3+NO_2-N) at Madison St. (M-2) in the South Branch Chicago River, 1975-1993. Data from MWRDGC.

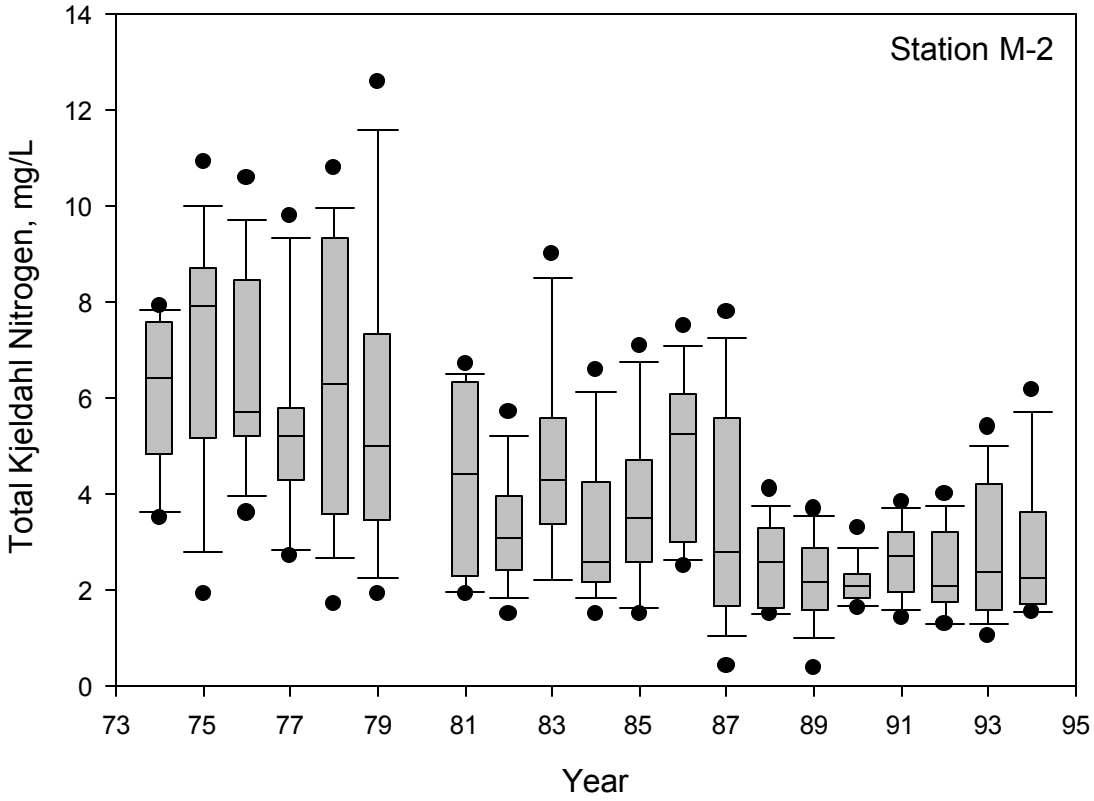

Figure C-4. Total Kjeldahl Nitrogen (TKN) at Madison St. (M-2) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

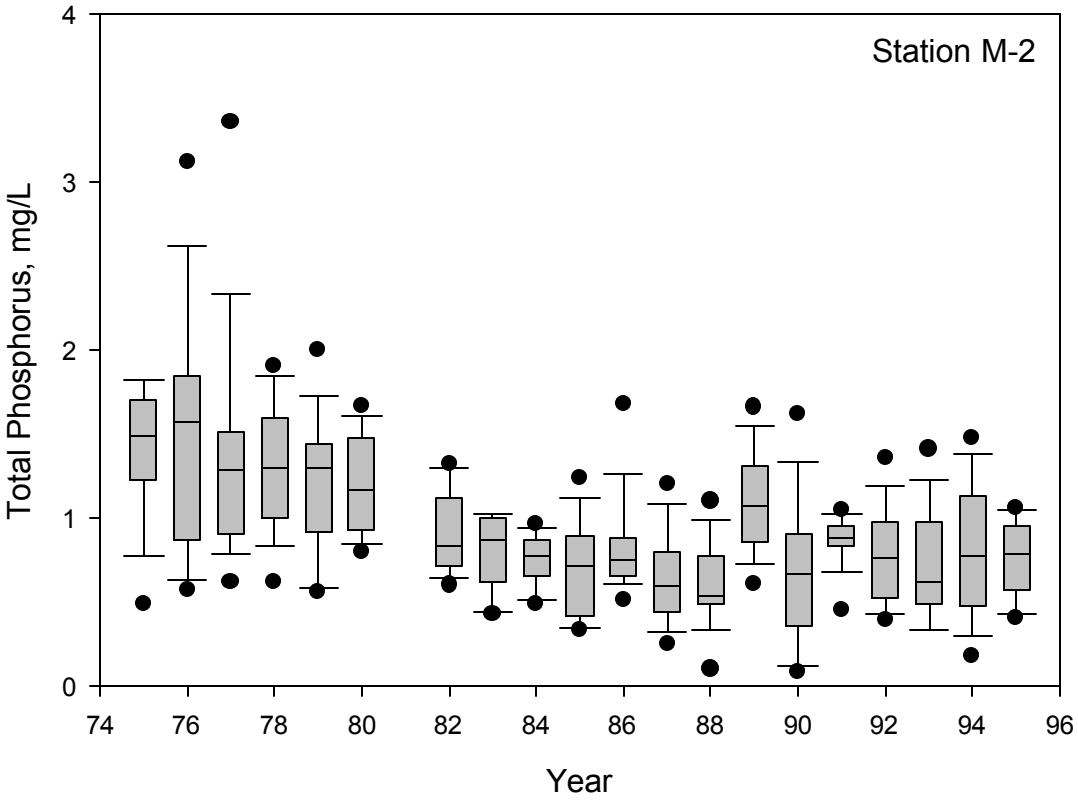

Figure C-5. Total Phosphorus (P) at Madison St. (M-2) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

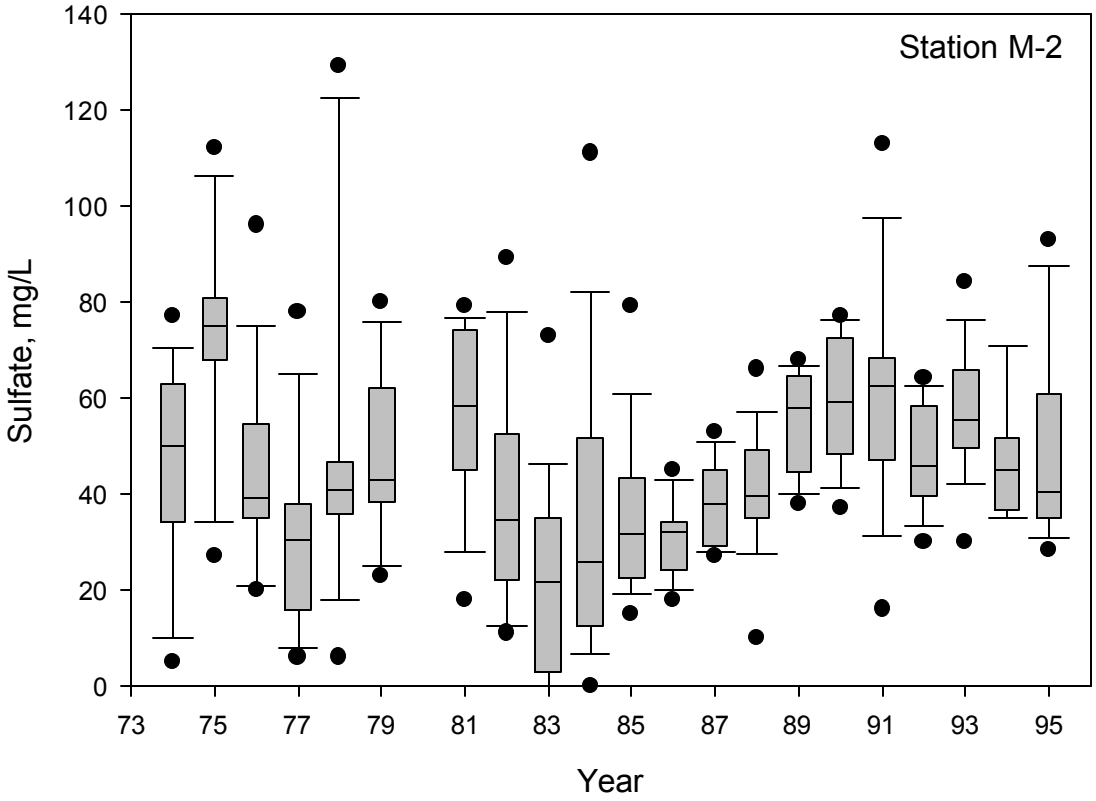

Figure C-6. Sulfate (SO_4) at Madison St. (M-2) in the South Branch Chicago River, 1974-1995. Data from MWRDGC.

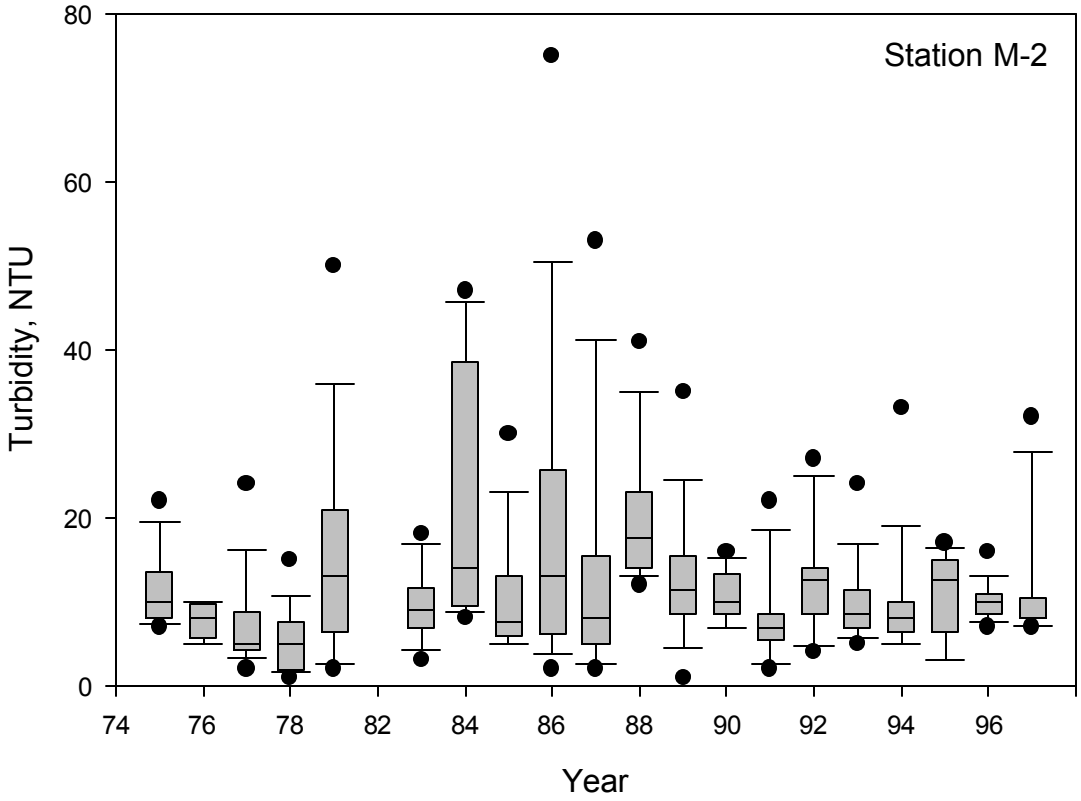

Figure C-7. Turbidity at Madison St. (M-2) in the South Branch Chicago River, 1974-1995. Data from MWRDGC.

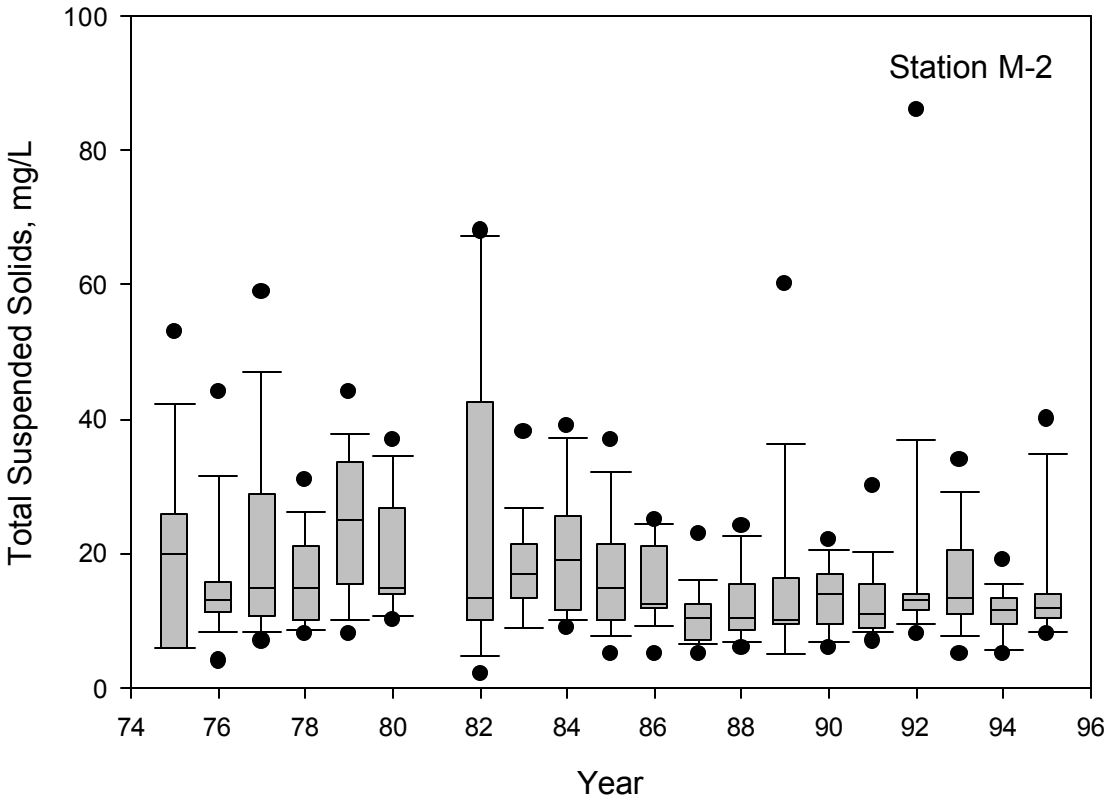

Figure C-8. Total Suspended Solids (TSS) at Madison St. (M-2) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

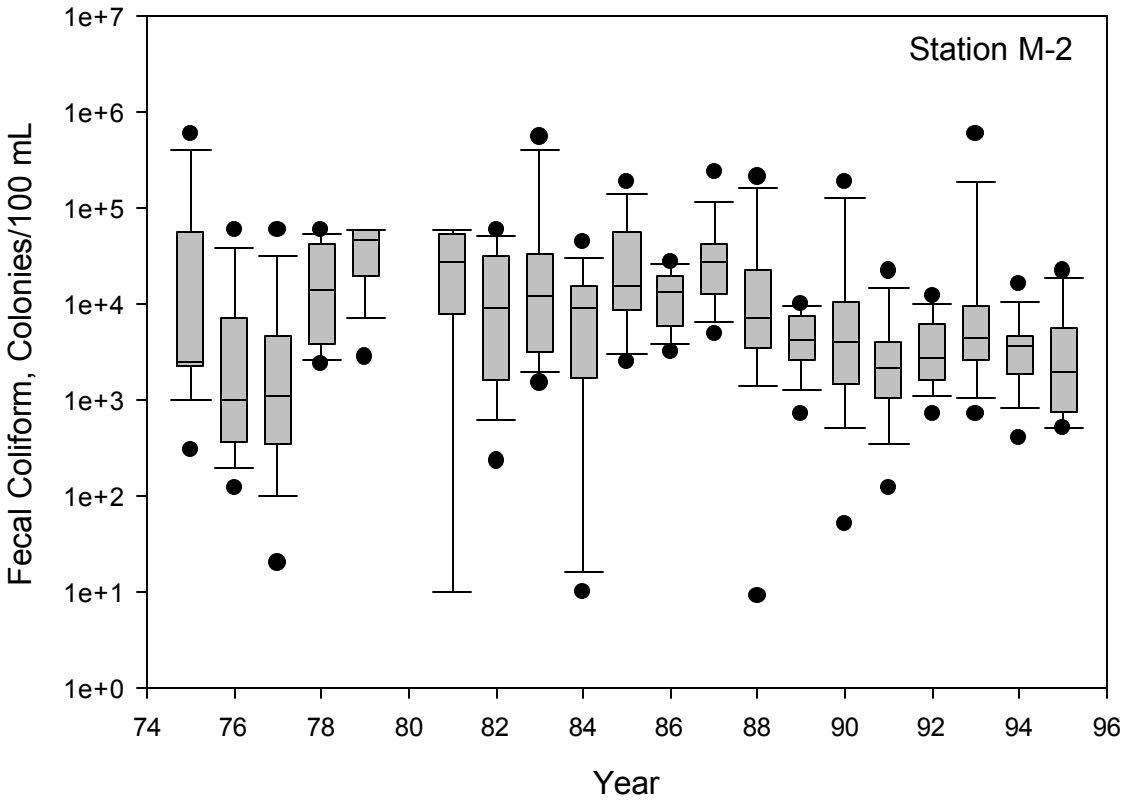

Figure C-9. Fecal Coliform Density at Madison St. (M-2) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

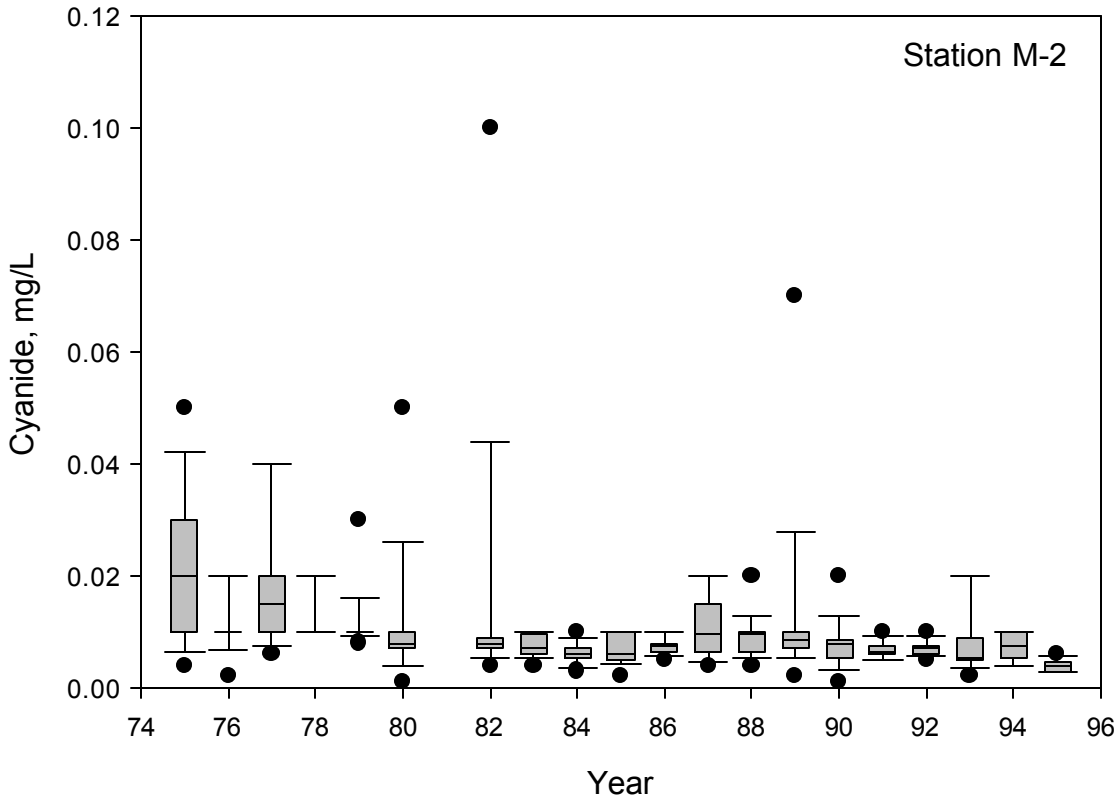

Figure C-10. Cyanide at Madison St. (M-2) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

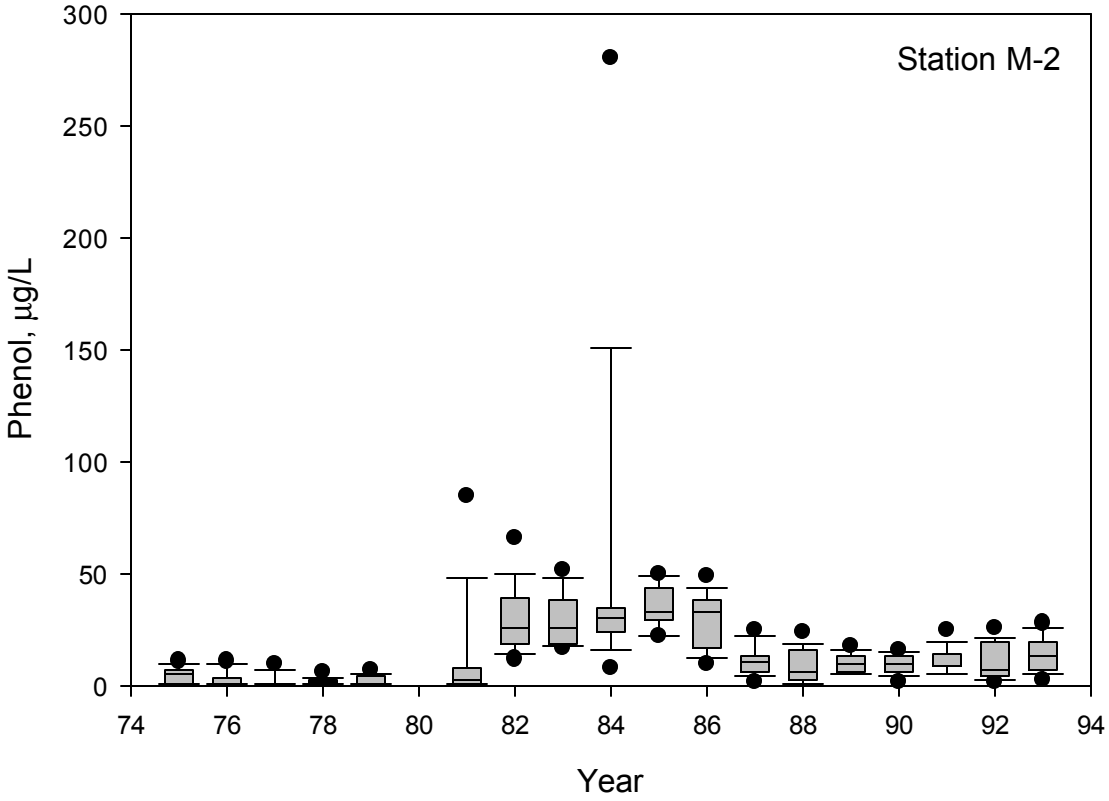

Figure C-11. Phenol at Madison St. (M-2) in the South Branch Chicago River, 1975-1993. Data from MWRDGC.

Appendix D. Box Plots for Station M-3,
South Branch Chicago River at Damen Ave.

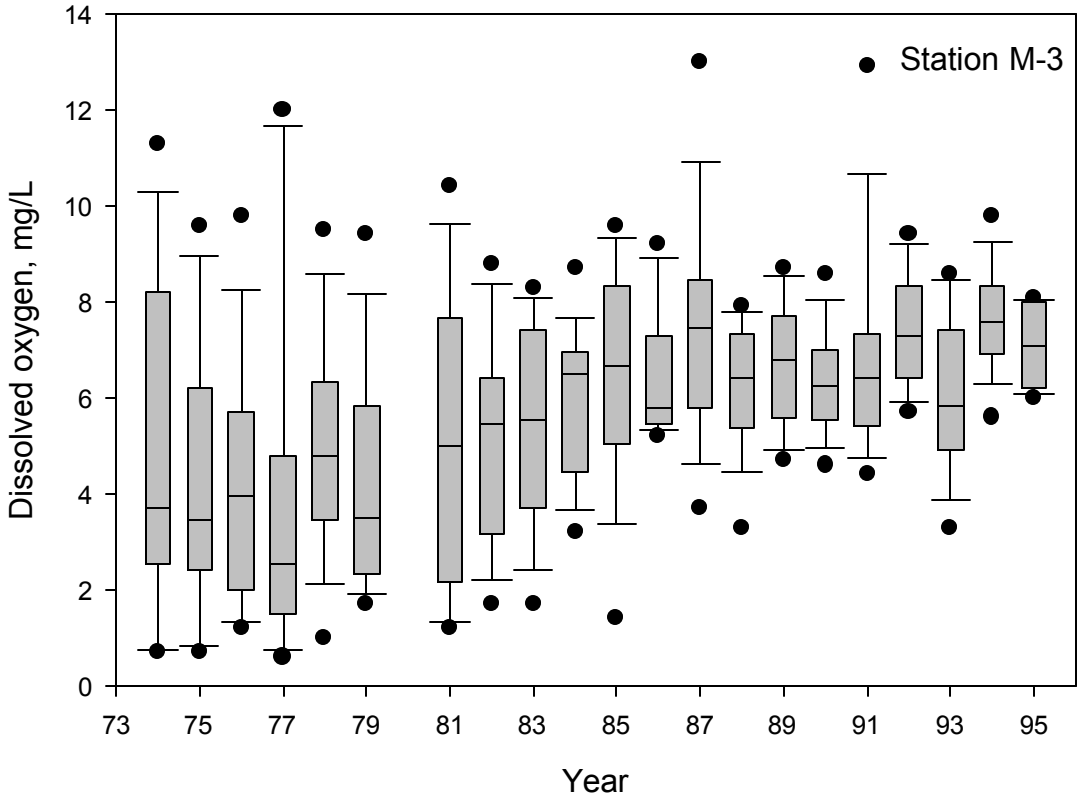

Figure D-1. Dissolved Oxygen (DO) at Damen Ave. (M-3) in the South Branch Chicago River, 1974-1995. Data from MWRDGC.

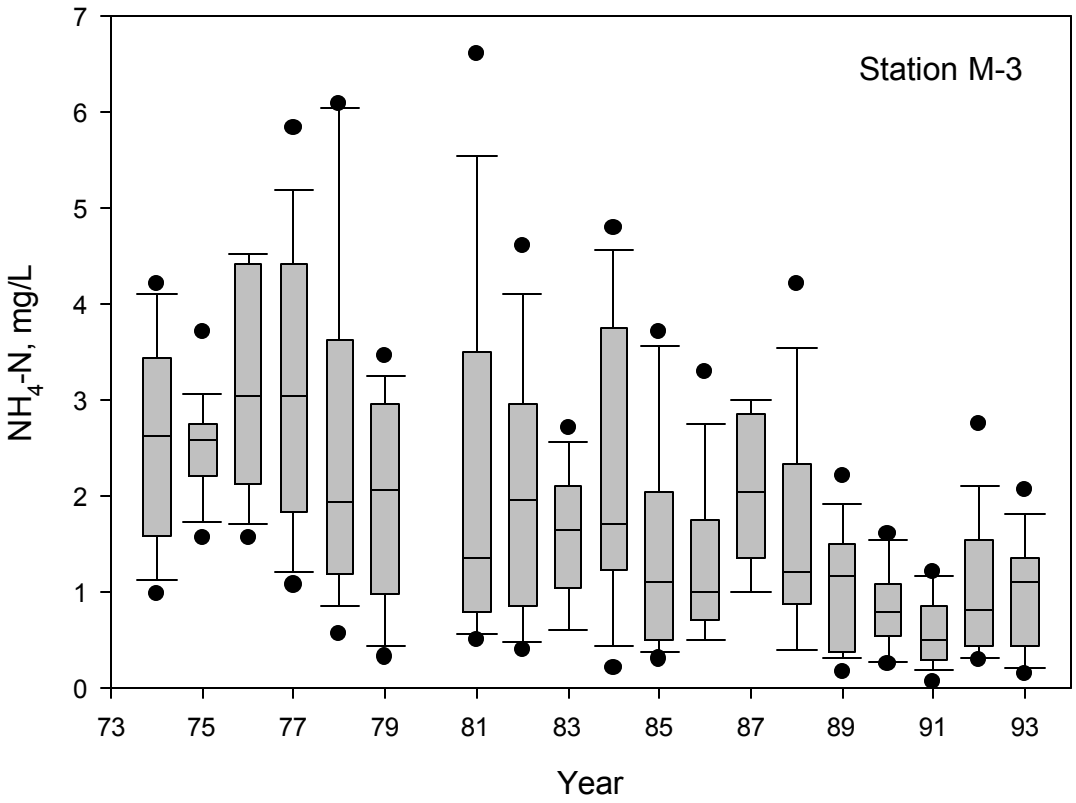

Figure D-2. Ammonia-Nitrogen (NH_4-N) at Damen Ave. (M-3) in the South Branch Chicago River, 1974-1993. Data from MWRDGC.

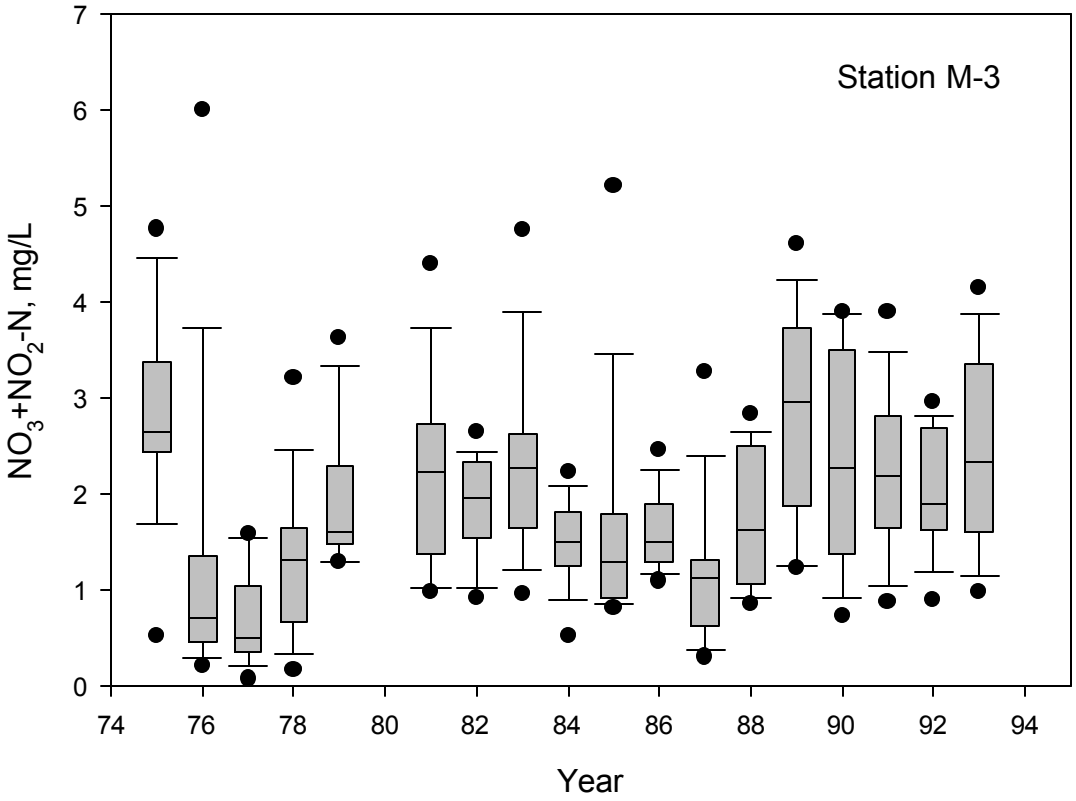

Figure D-3. Nitrate and Nitrite-Nitrogen (NO_3+NO_2-N) at Damen Ave. (M-3) in the South Branch Chicago River, 1975-1993. Data from MWRDGC.

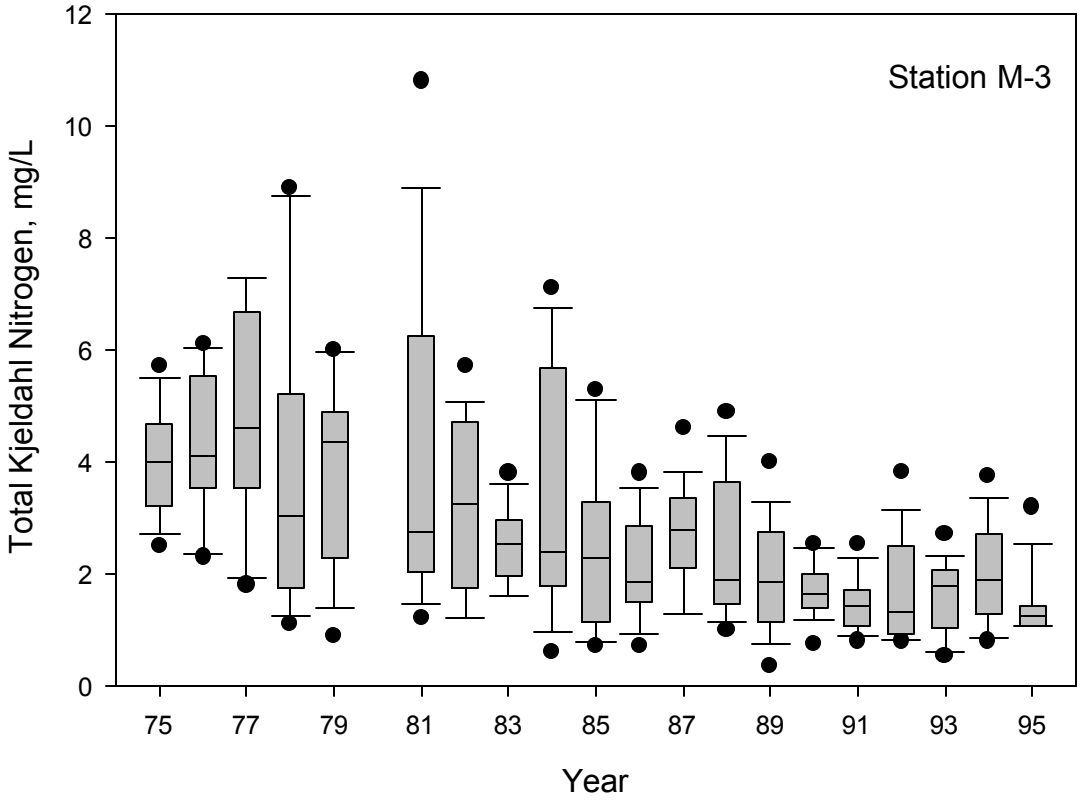

Figure D-4. Total Kjeldahl Nitrogen (TKN) at Damen Ave. (M-3) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

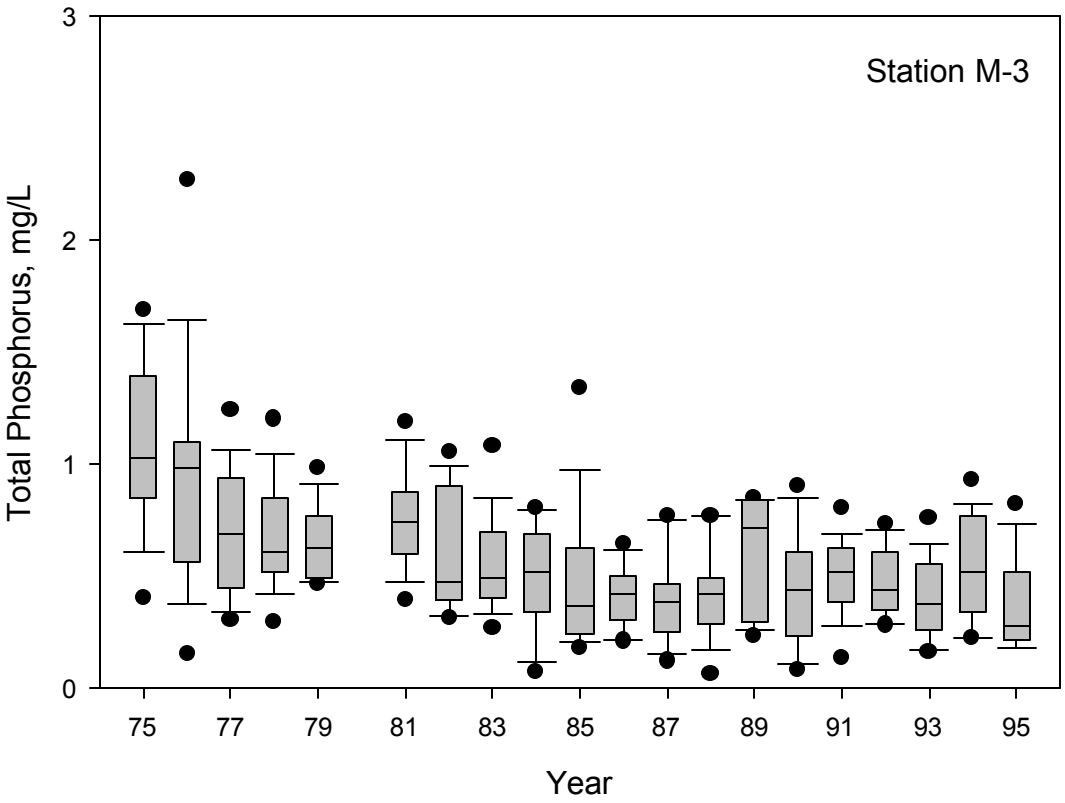

Figure D-5. Total Phosphorus (P) at Damen Ave. (M-3) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

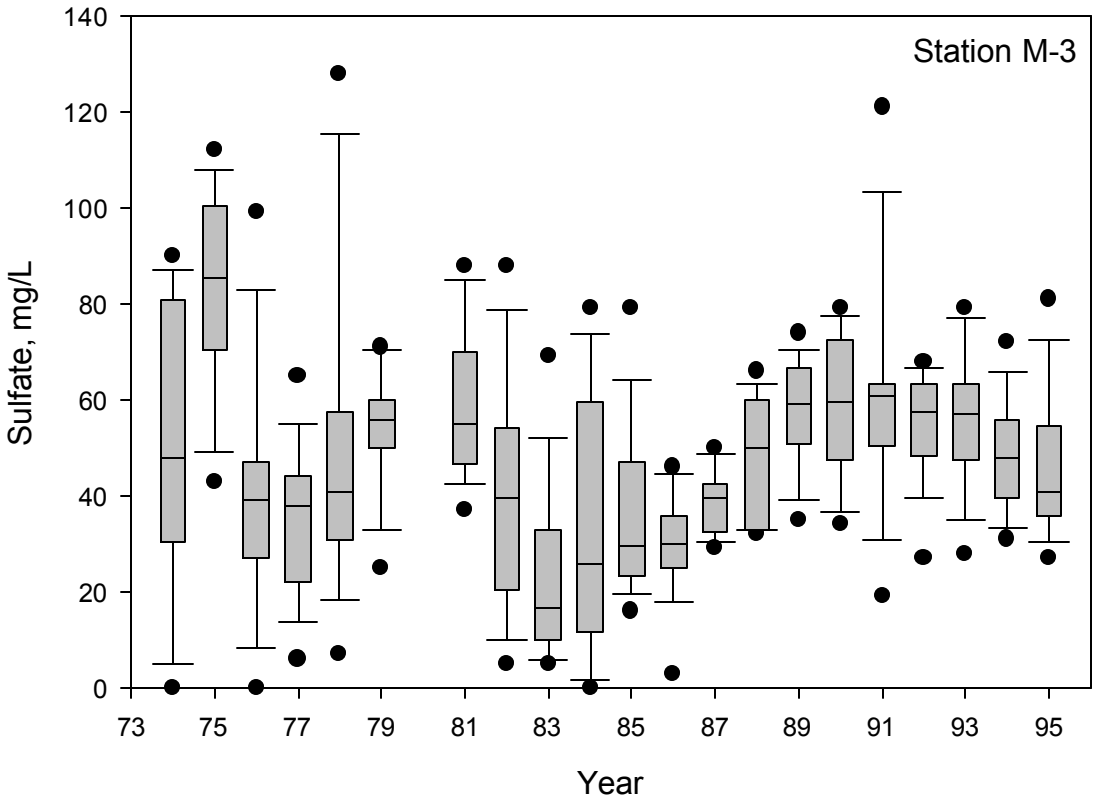

Figure D-6. Sulfate (SO_4) at Damen Ave. (M-3) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

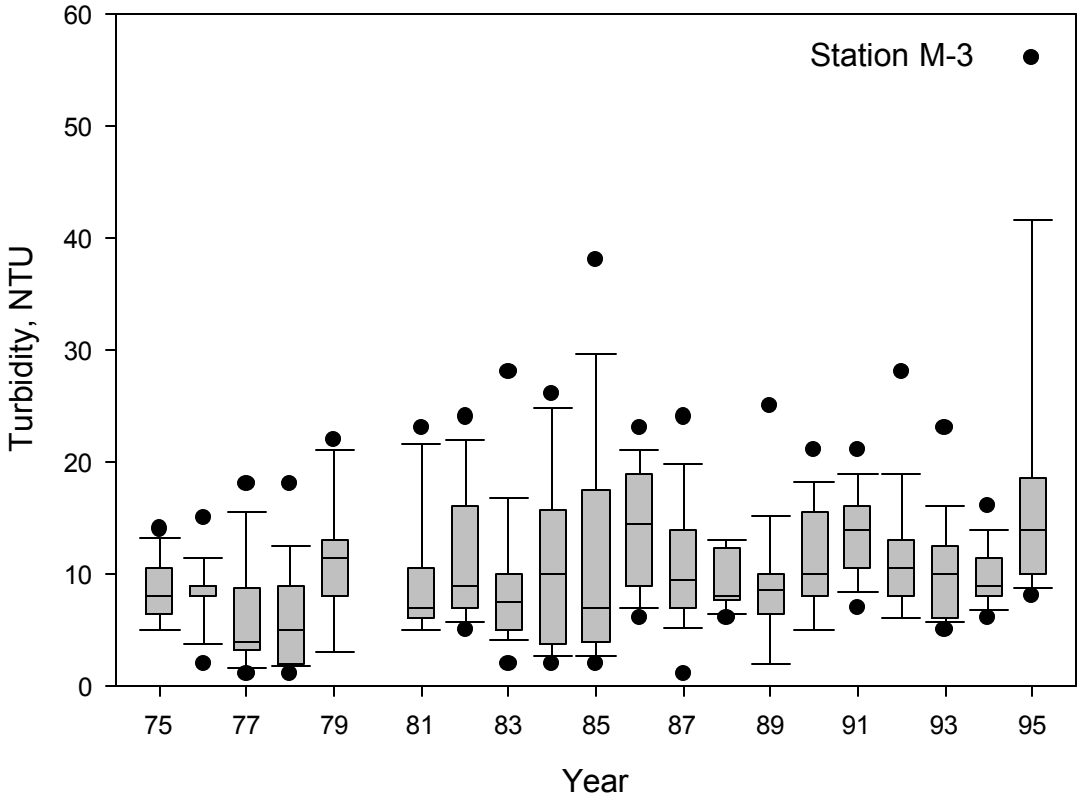

Figure D-7. Turbidity at Damen Ave. (M-3) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

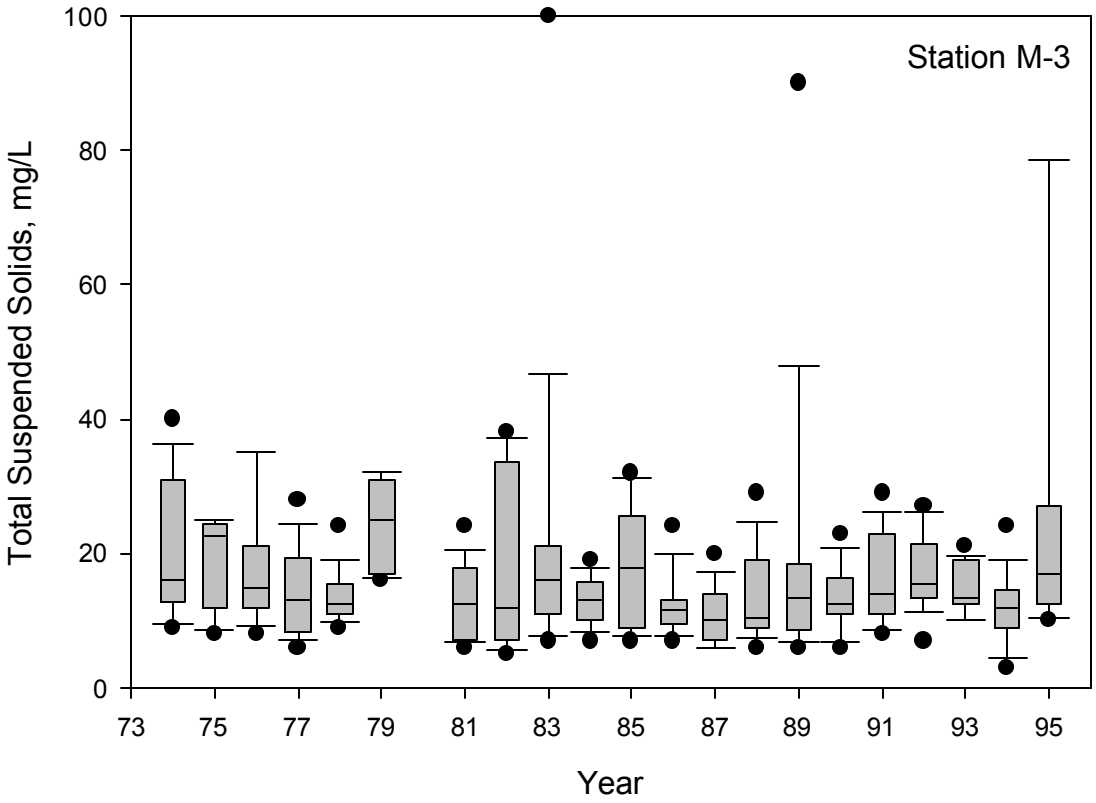

Figure D-8. Total Suspended Solids (TSS) at Damen Ave. (M-3) in the South Branch Chicago River, 1974-1995. Data from MWRDGC.

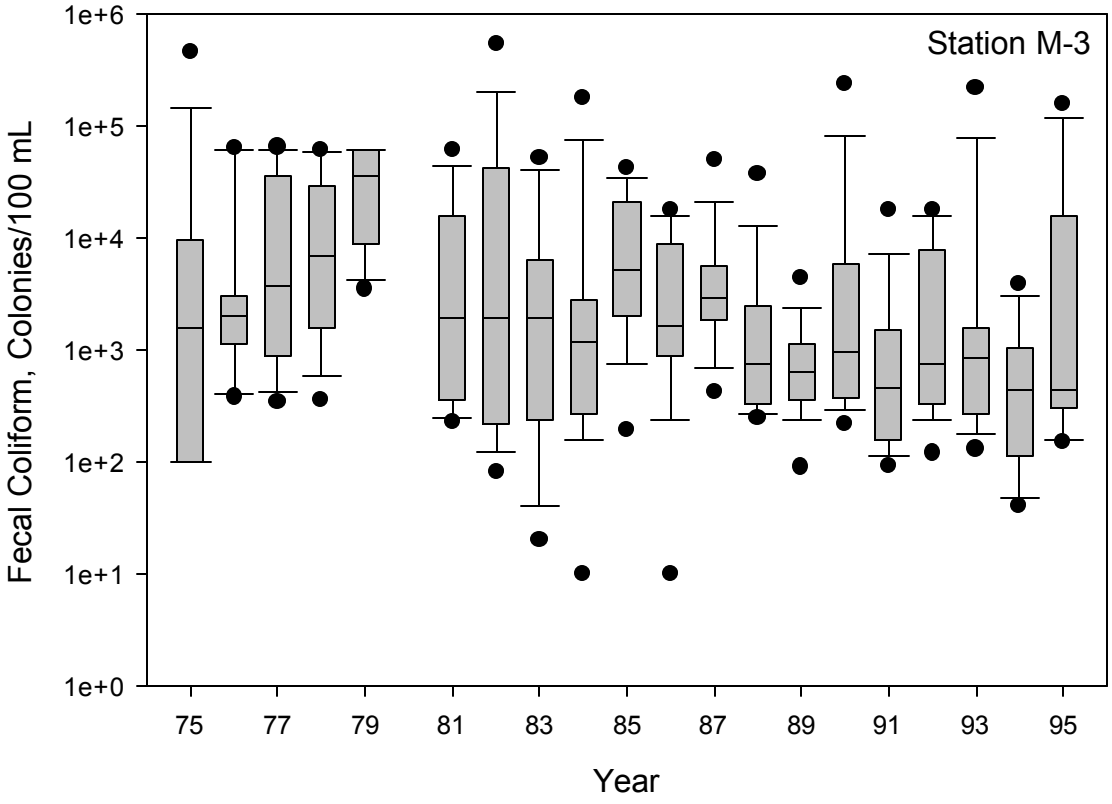

Figure D-9. Fecal Coliform Density at Damen Ave. (M-3) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

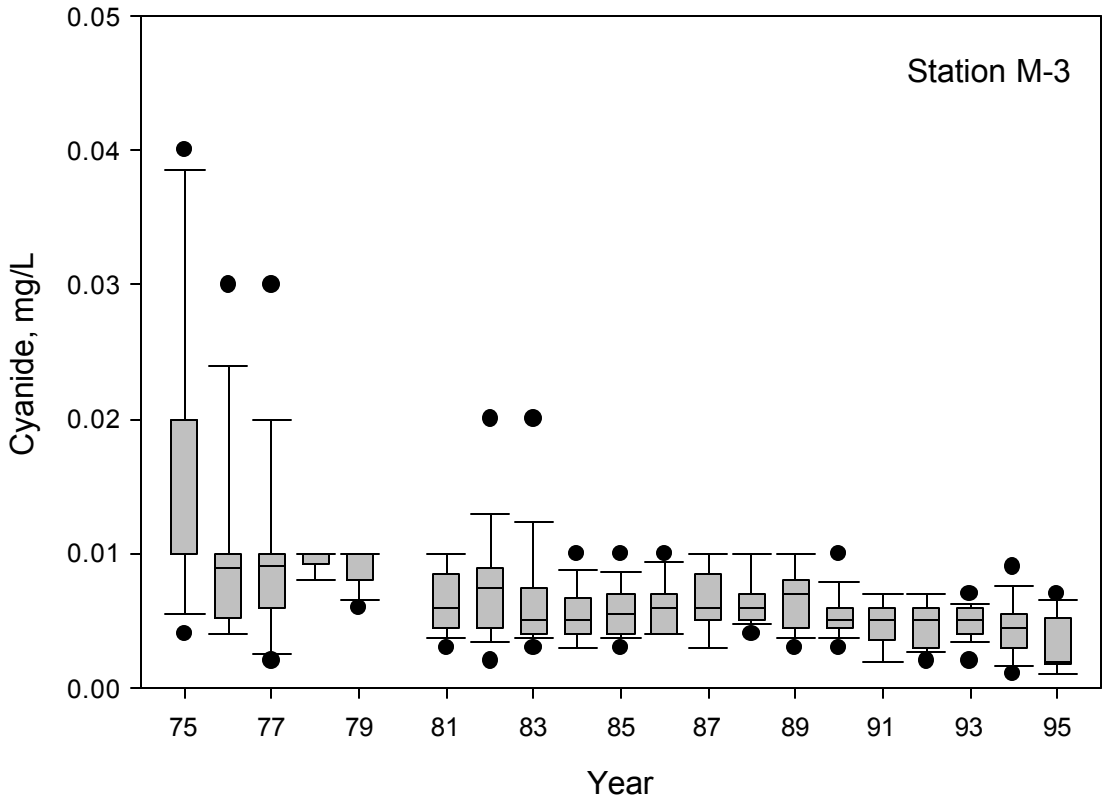

Figure D-10. Cyanide at Damen Ave. (M-3) in the South Branch Chicago River, 1975-1995. Data from MWRDGC.

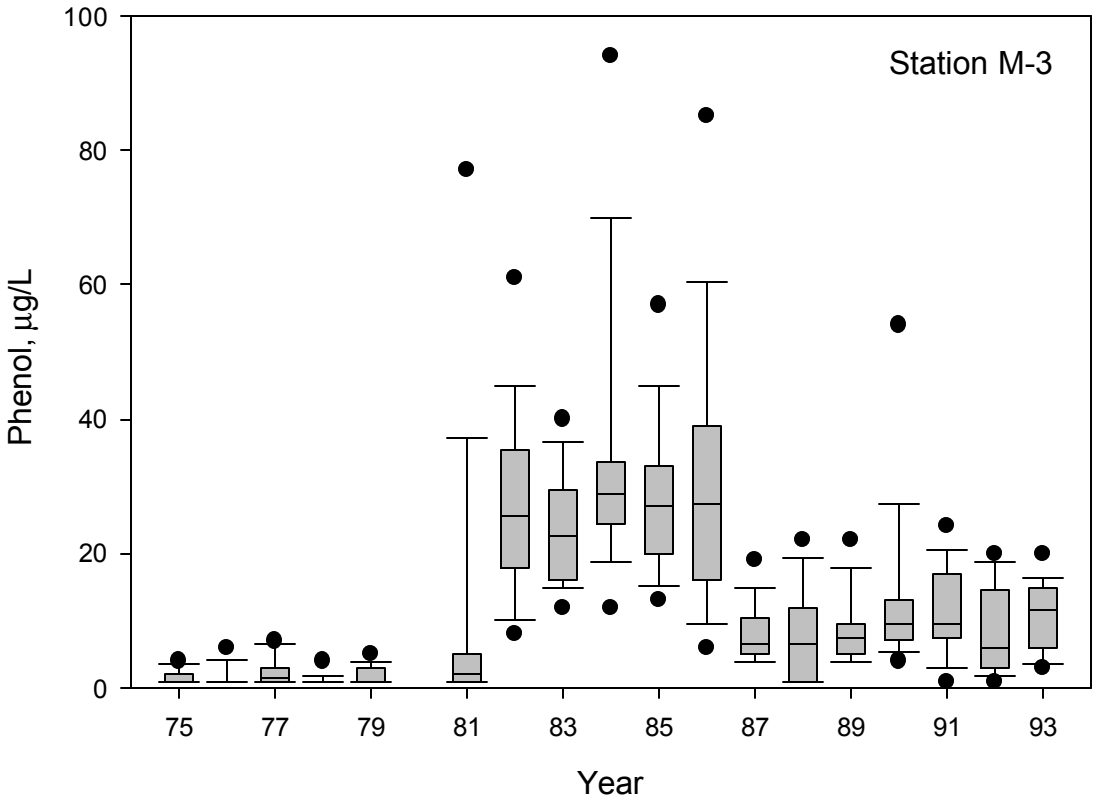

Figure D-11. Phenol at Damen Ave. (M-3) in the South Branch Chicago River, 1975-1993. Data from MWRDGC.

Appendix E. Box Plots for Station M-4, Chicago Sanitary and Ship Canal at Cicero Ave.

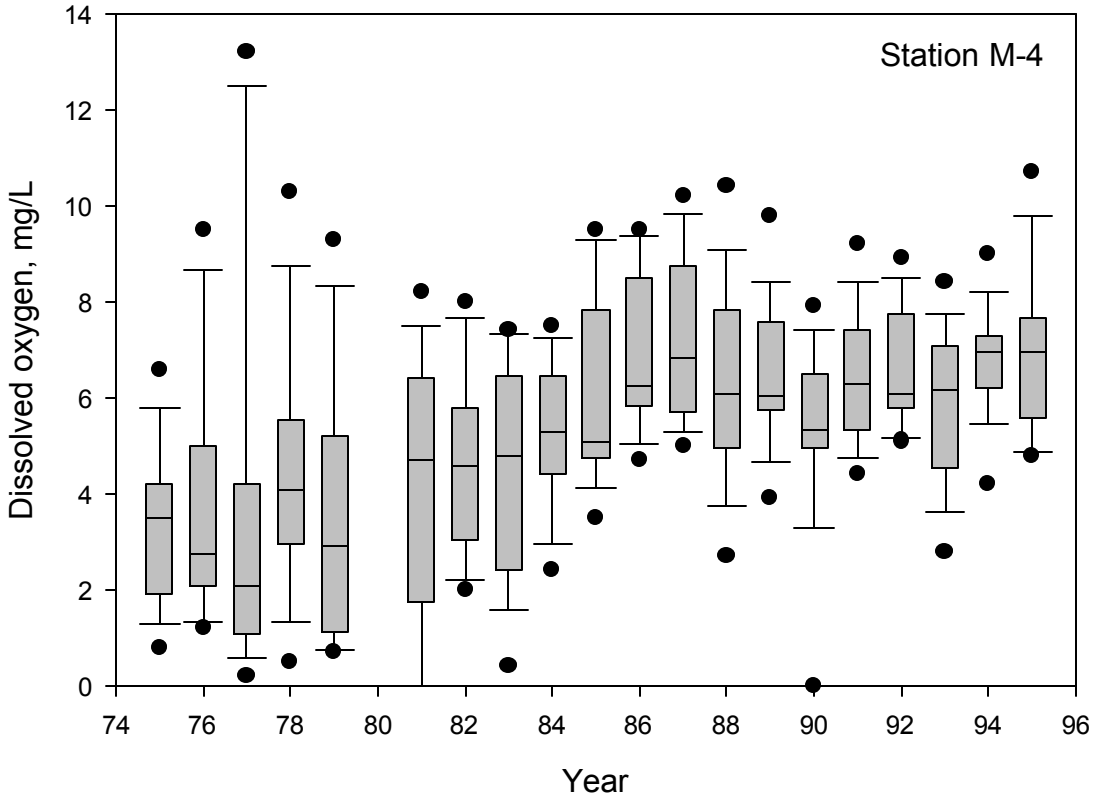

Figure E-1. Dissolved Oxygen (DO) at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

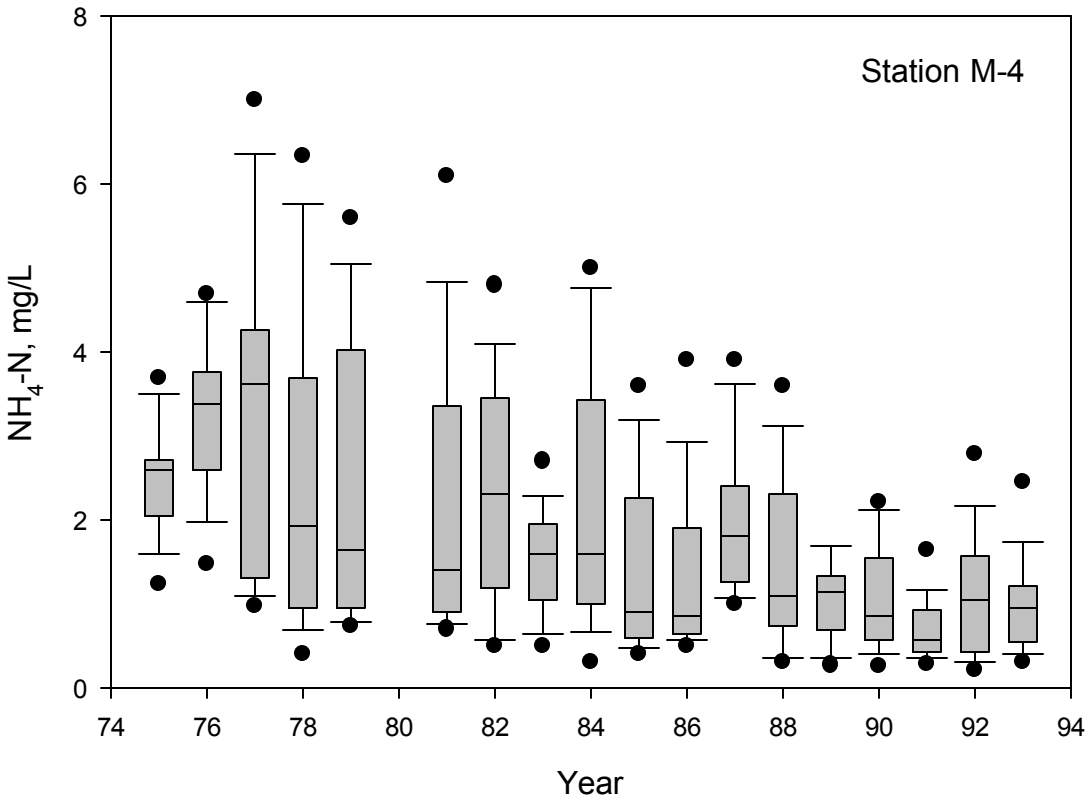

Figure E-2. Ammonia-Nitrogen (NH_4-N) at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1993. Data from MWRDGC.

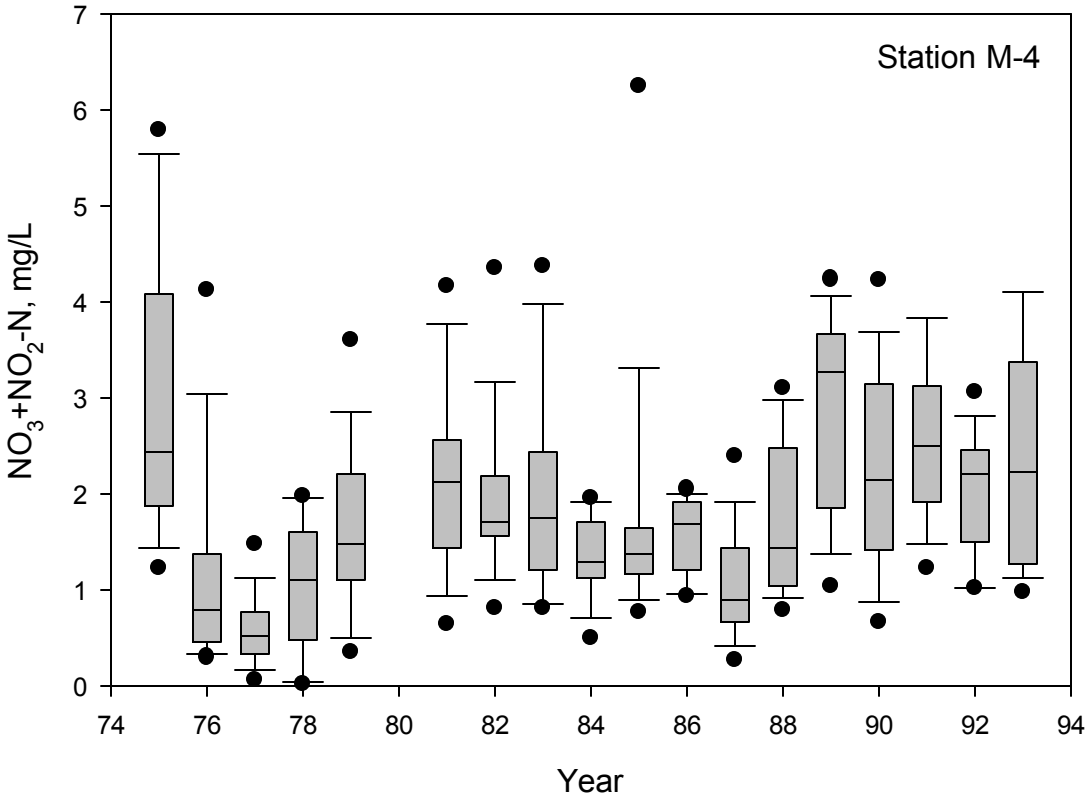

Figure E-3. Nitrate and Nitrite-Ammonia (NO_3+NO_2-N) at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1993. Data from MWRDGC.

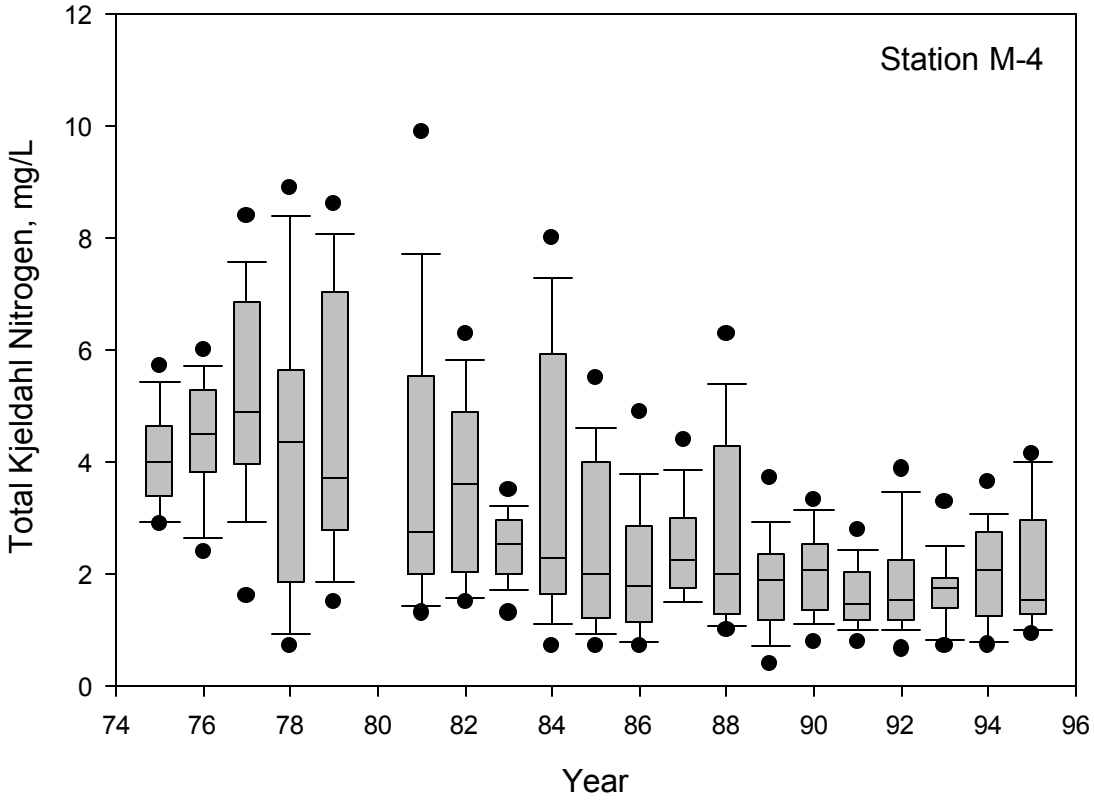

Figure E-4. Total Kjeldahl Nitrogen (TKN) at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

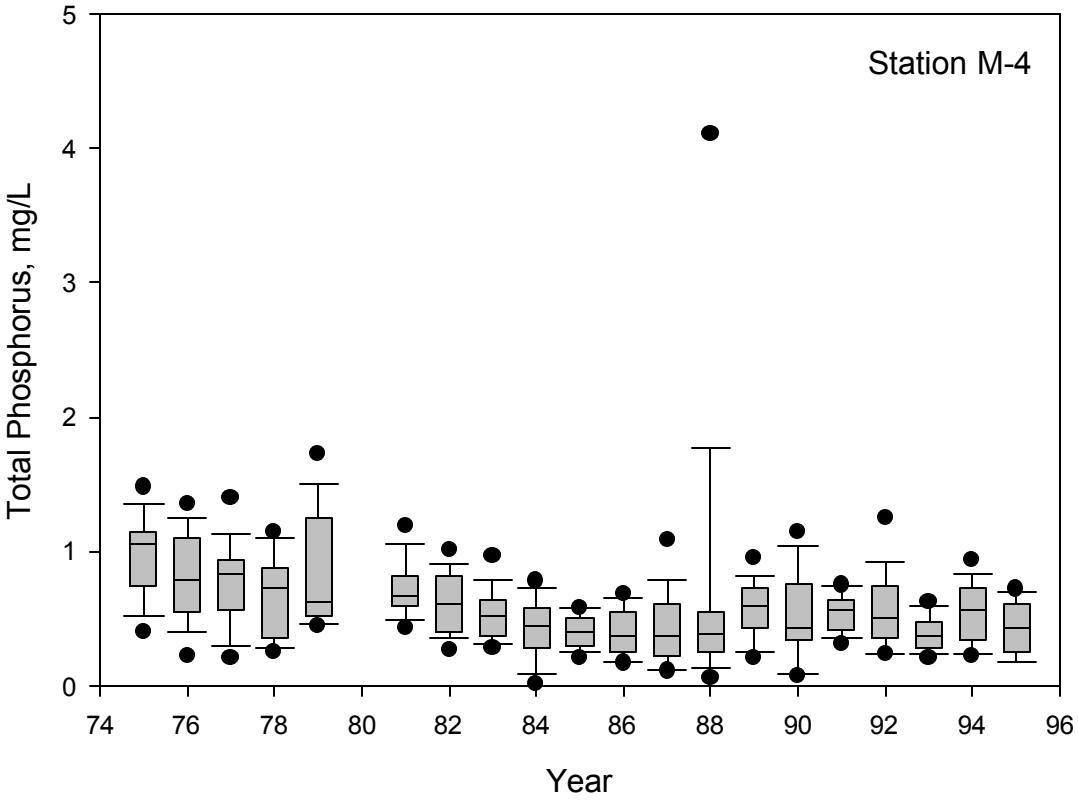

Figure E-5. Total Phosphorus (P) at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

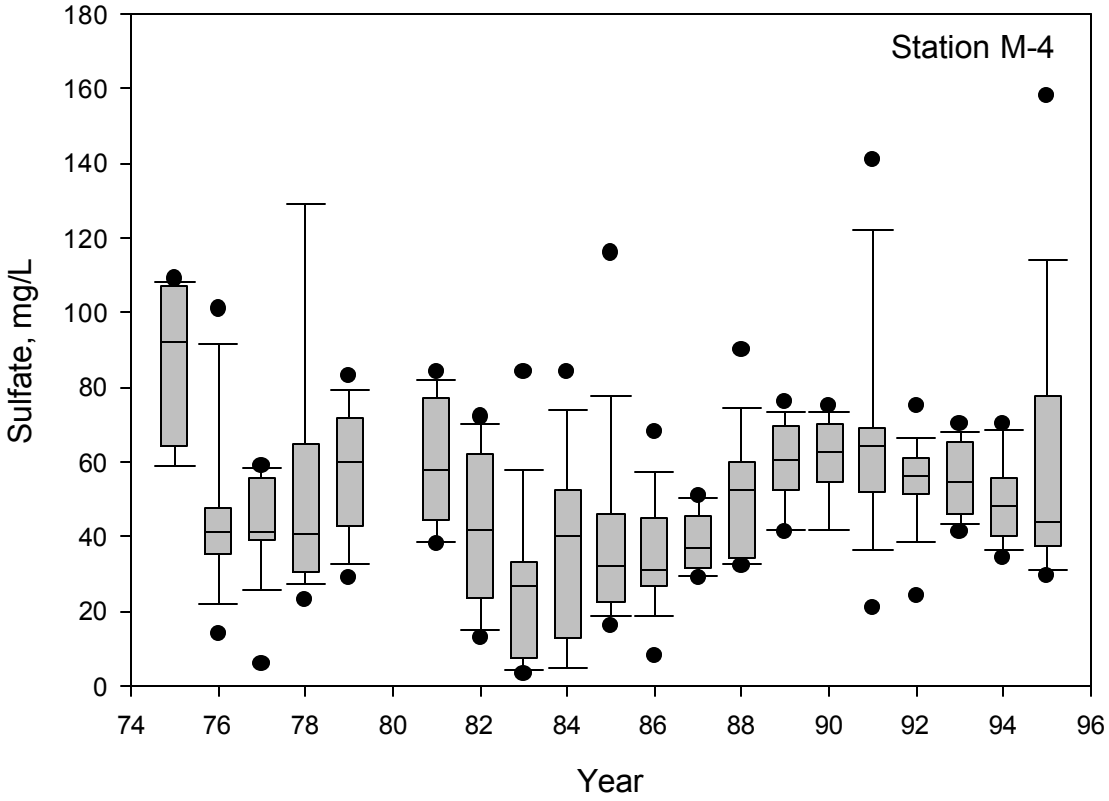

Figure E-6. Sulfate (SO_4) at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

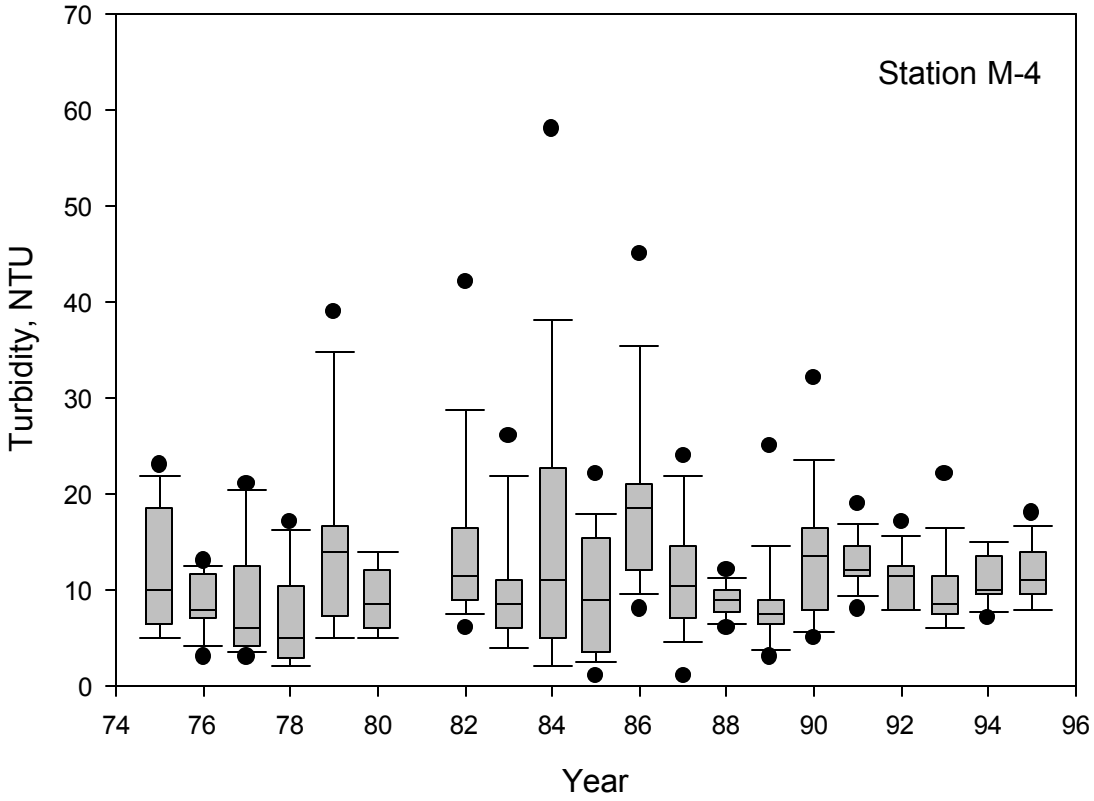

Figure E-7. Turbidity at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

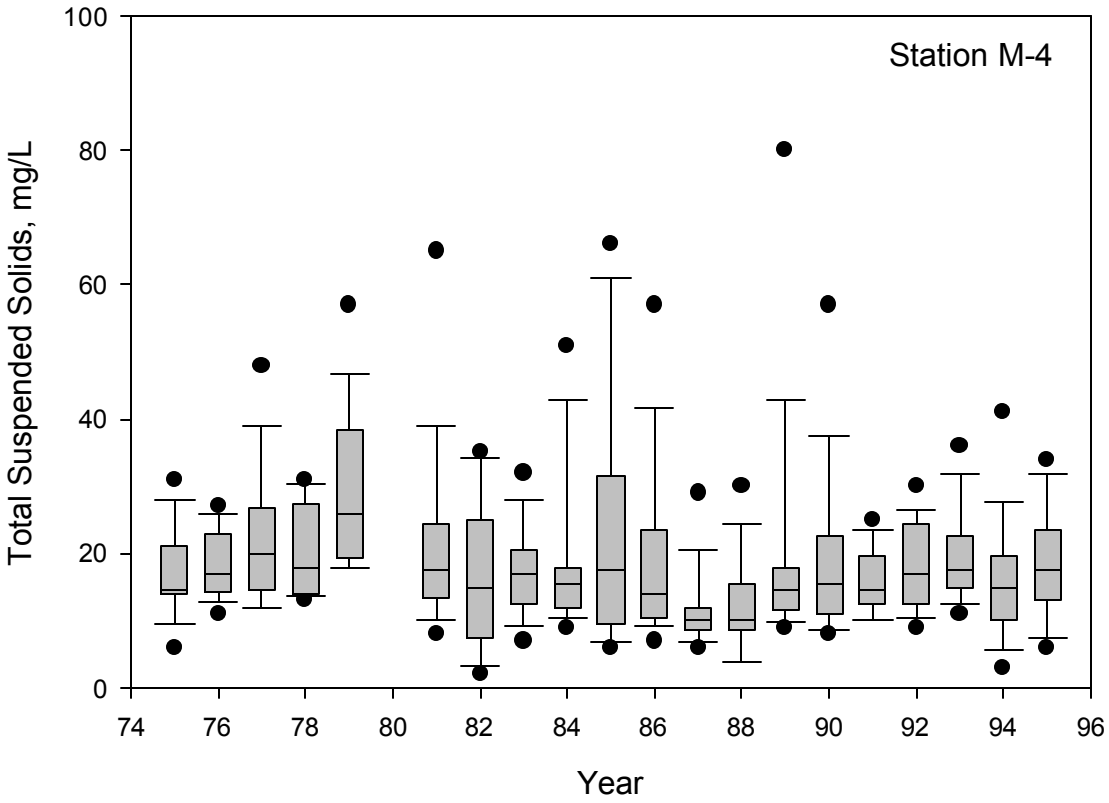

Figure E-8. Total Suspended Solids (TSS) at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

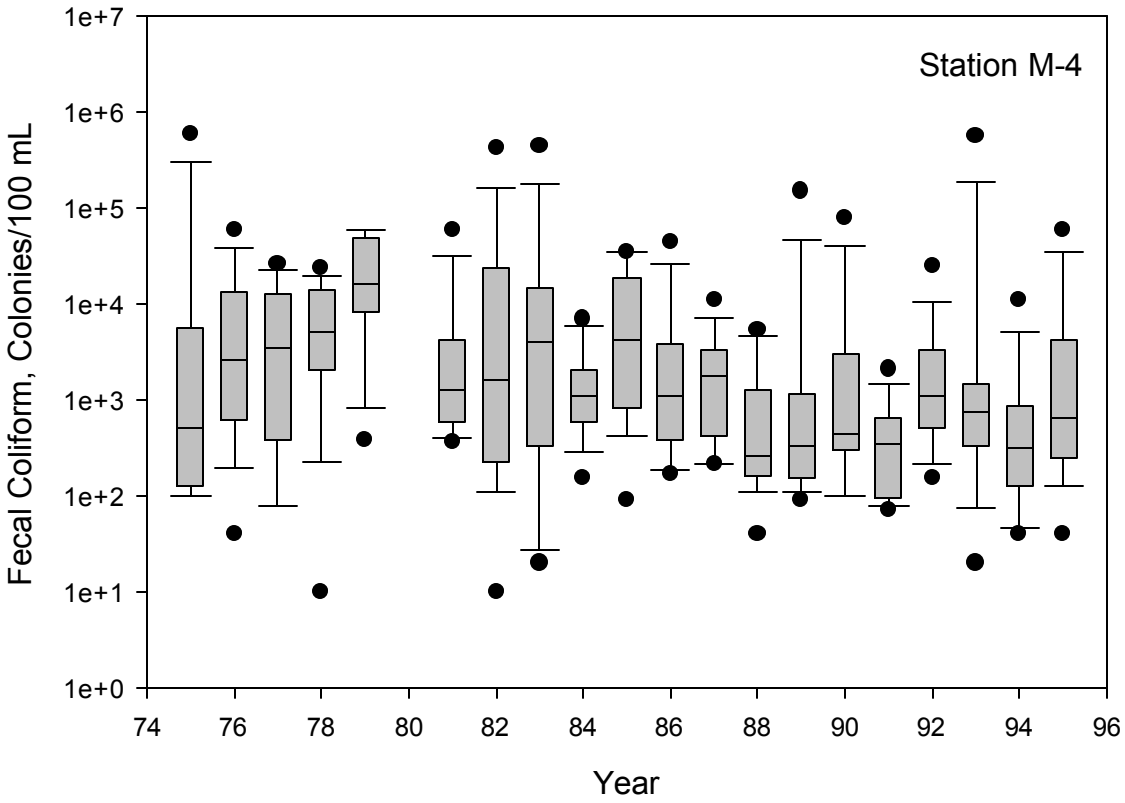

Figure E-9. Fecal Coliform Density at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

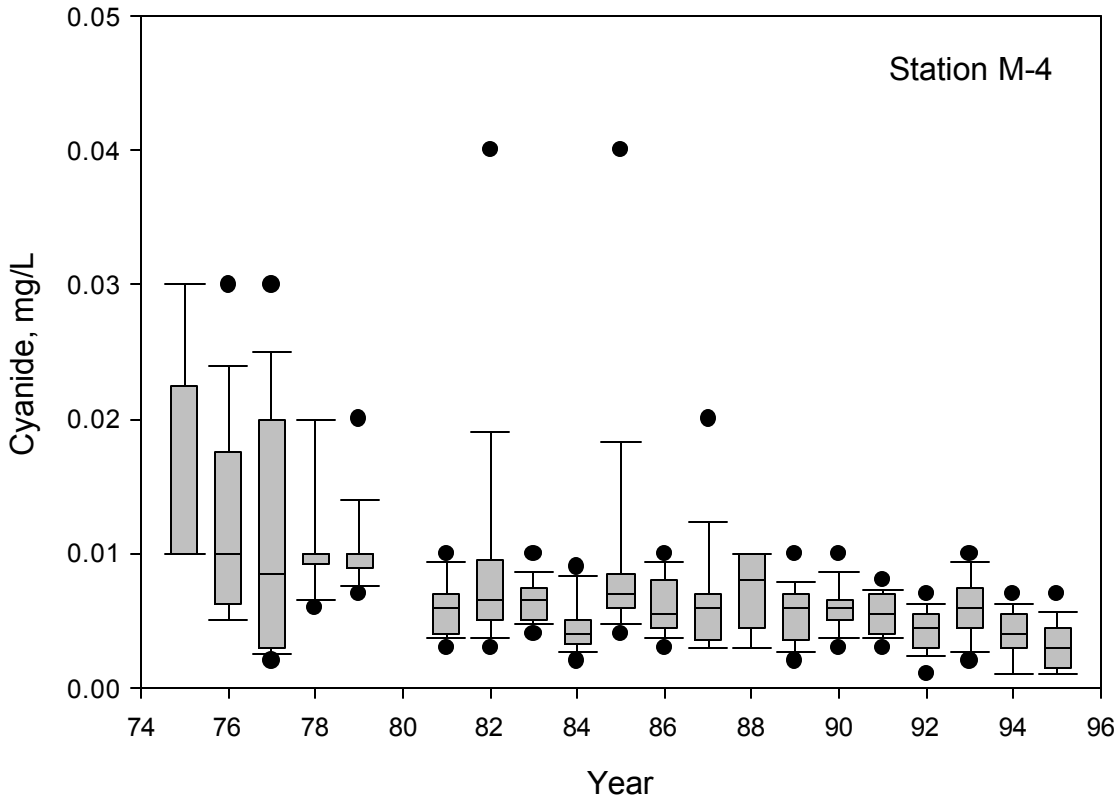

Figure E-10. Cyanide at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

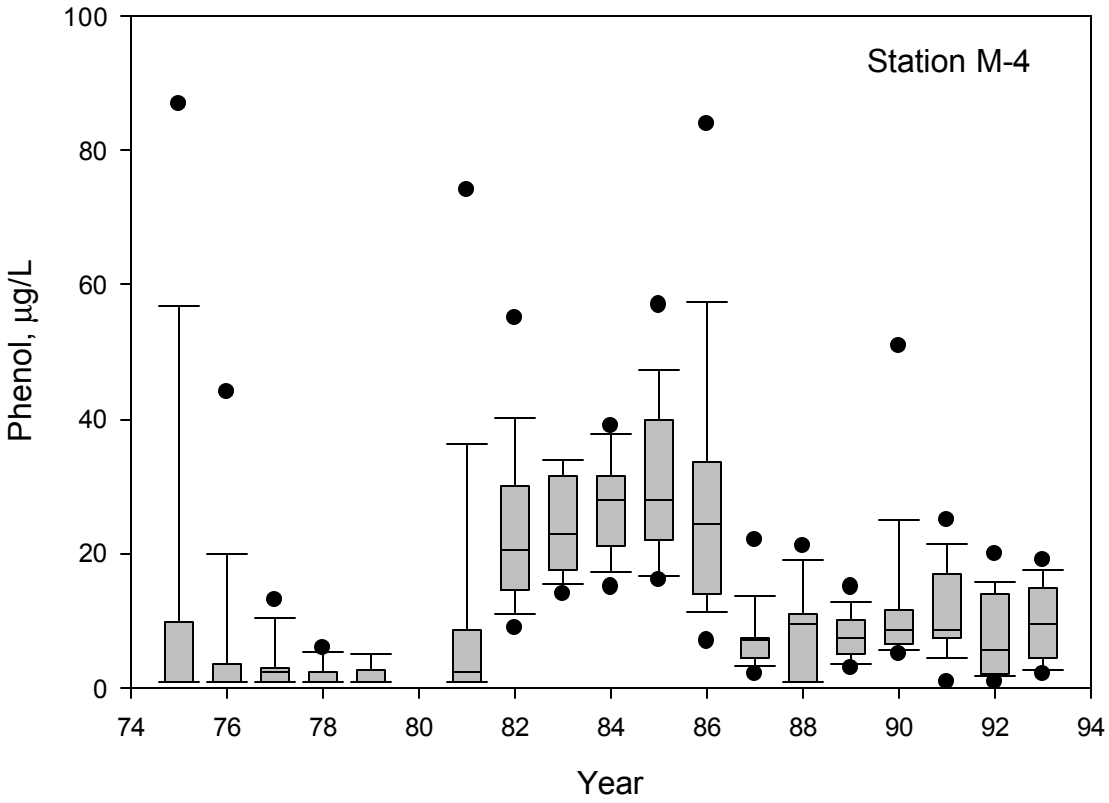

Figure E-11. Phenol at Cicero Ave. (M-4) in the Chicago Sanitary and Ship Canal, 1975-1993. Data from MWRDGC.

Appendix F. Box Plots for Station M-5,
Chicago Sanitary and Ship Canal at Harlem Ave.

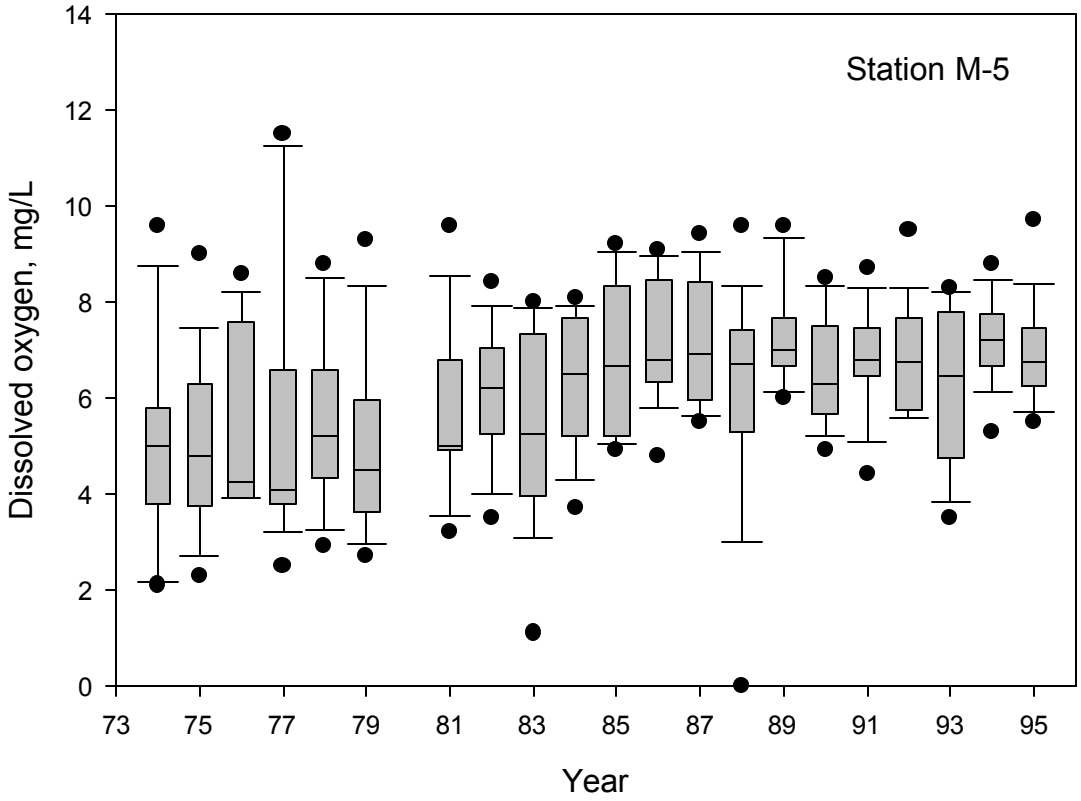

Figure F-1. Dissolved Oxygen (DO) at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1974-1995. Data from MWRDGC.

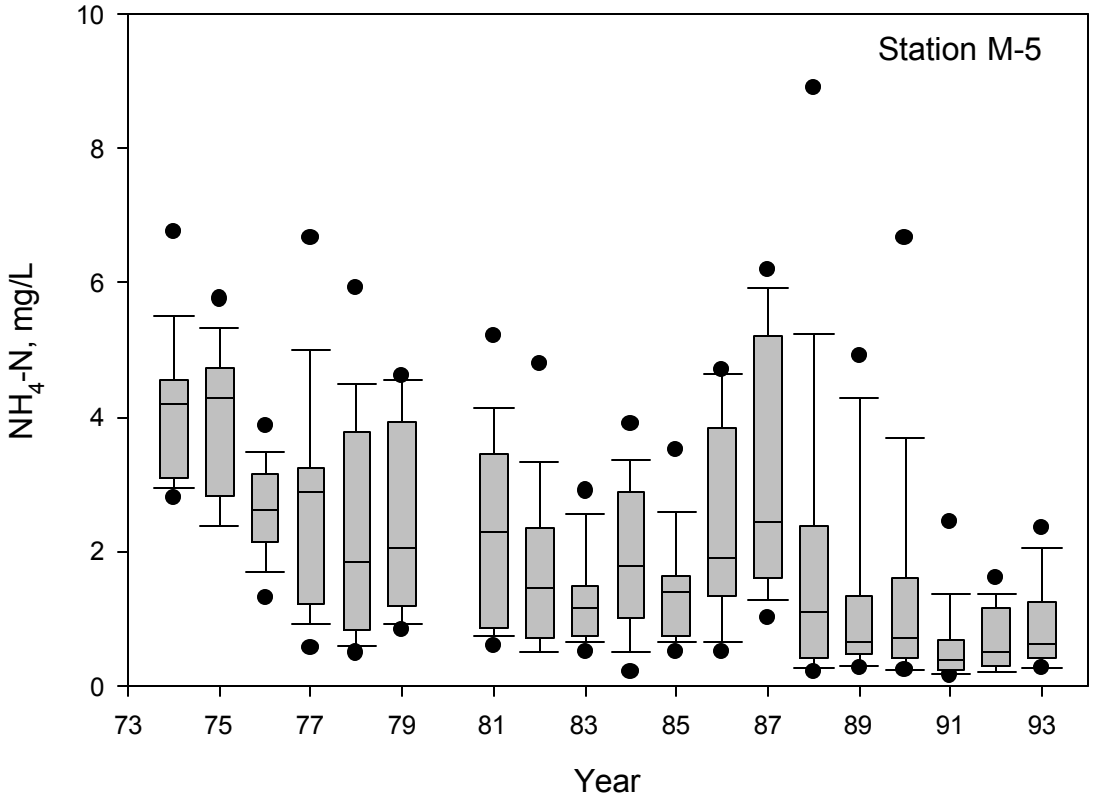

Figure F-2. Ammonia-Nitrogen (NH_4-N) at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1974-1993. Data from MWRDGC.

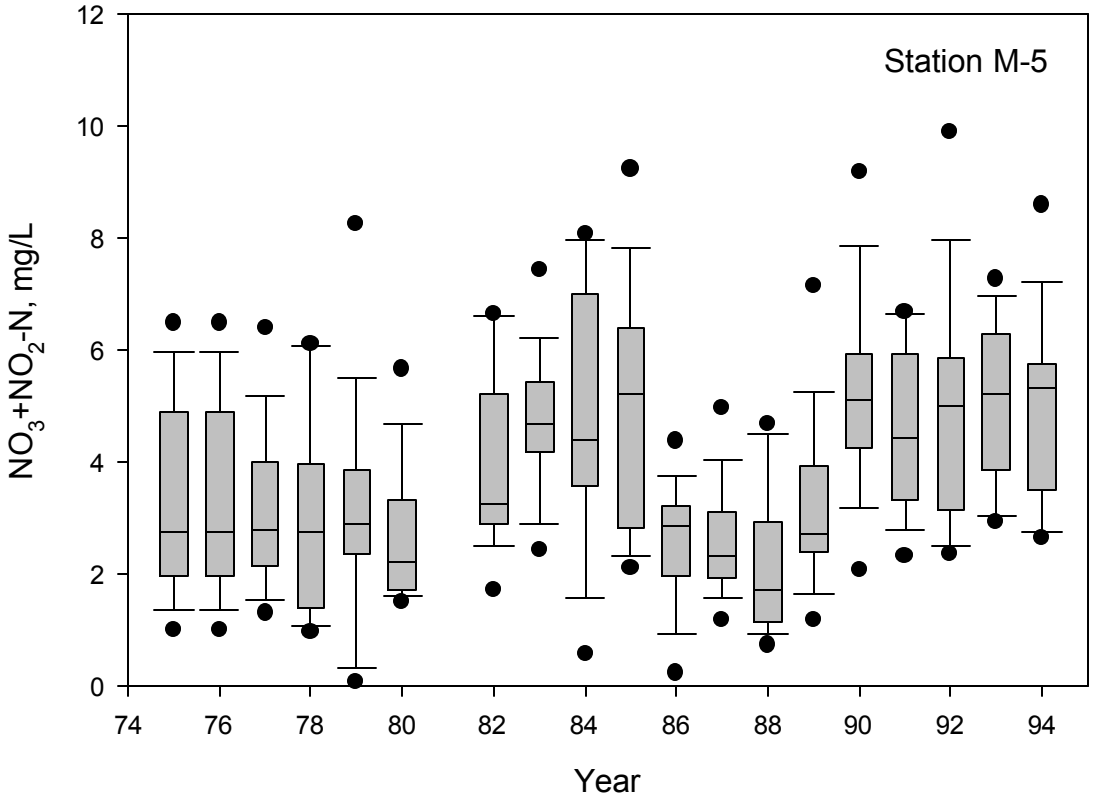

Figure F-3. Nitrate and Nitrite-Nitrogen (NO_2+NO_2-N) at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1975-1994. Data from MWRDGC.

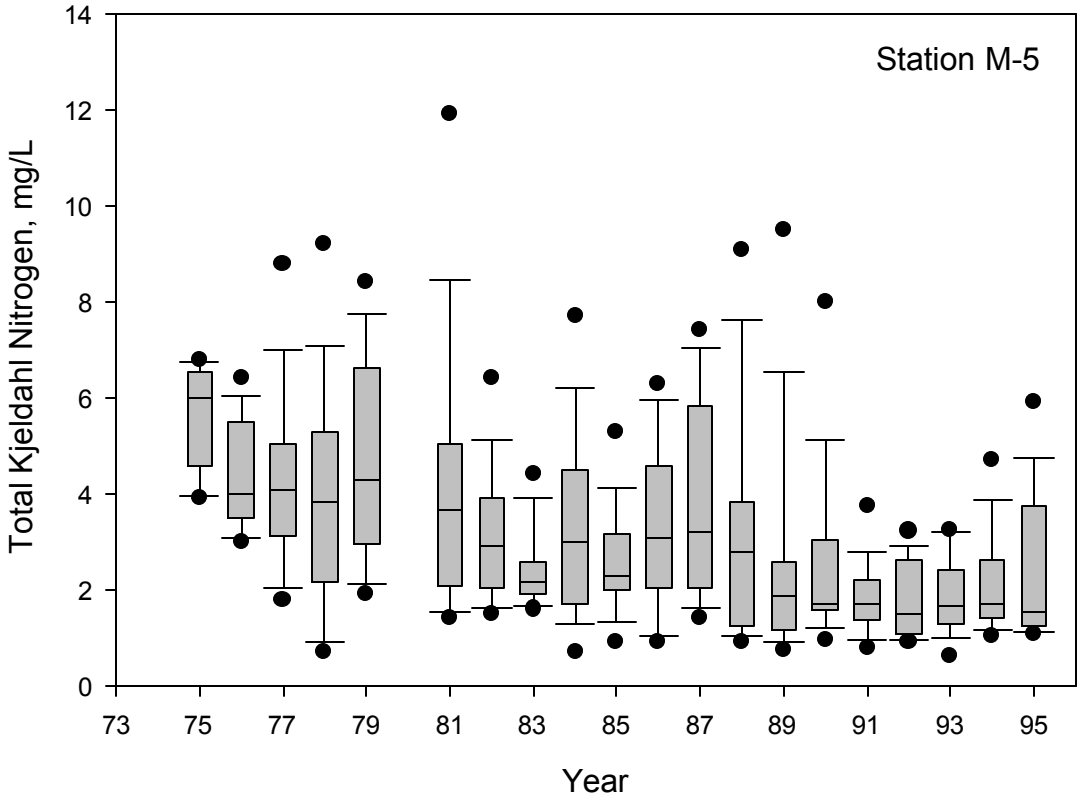

Figure F-4. Total Kjeldahl Nitrogen (TKN) at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

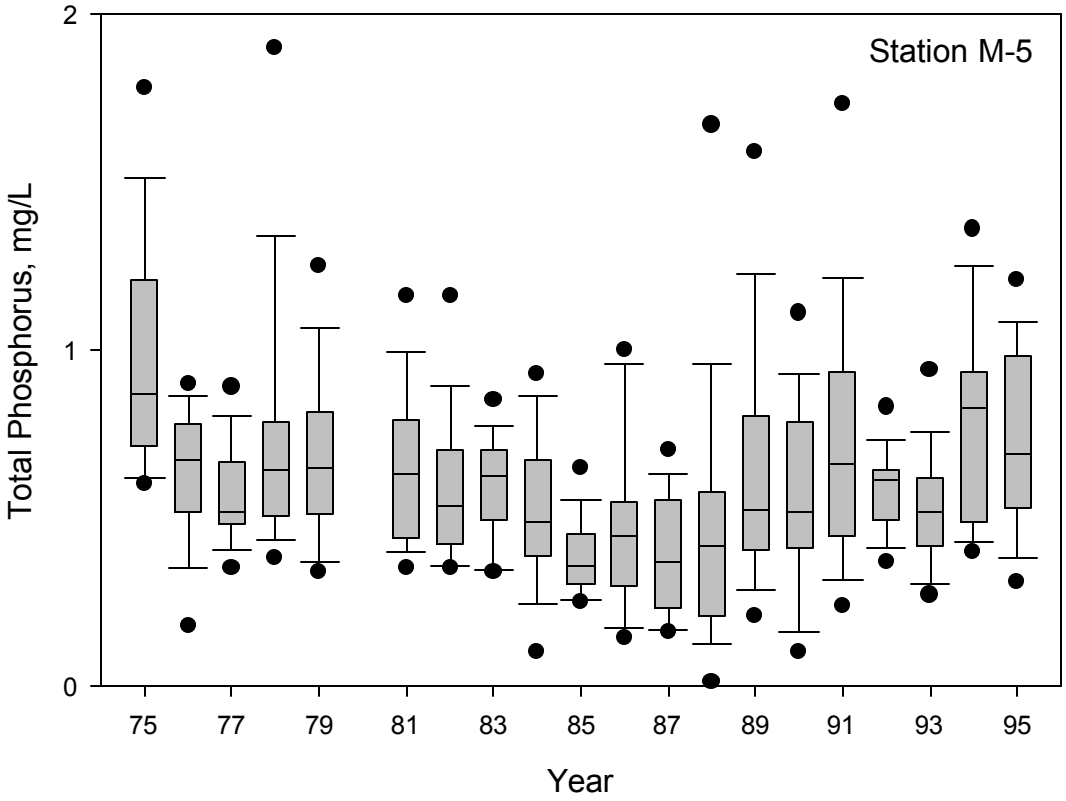

Figure F-5. Total Phosphorus (P) at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

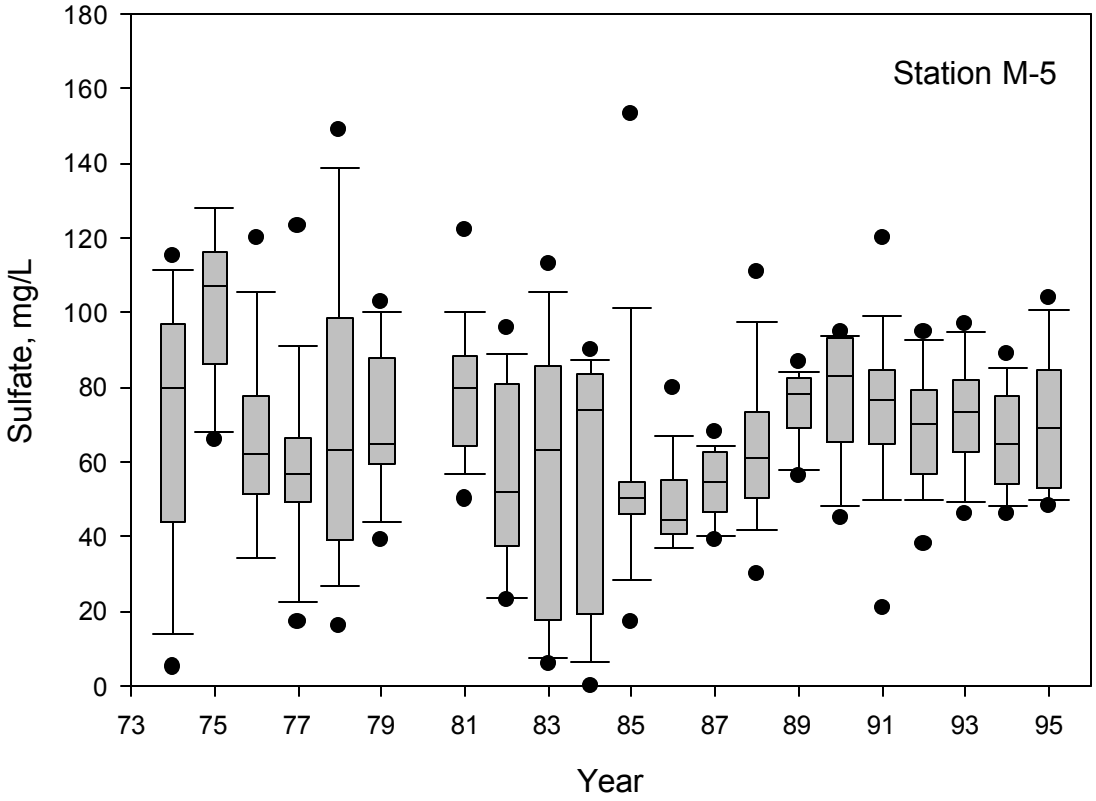

Figure F-6. Sulfate (SO_4) at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1974-1995. Data from MWRDGC.

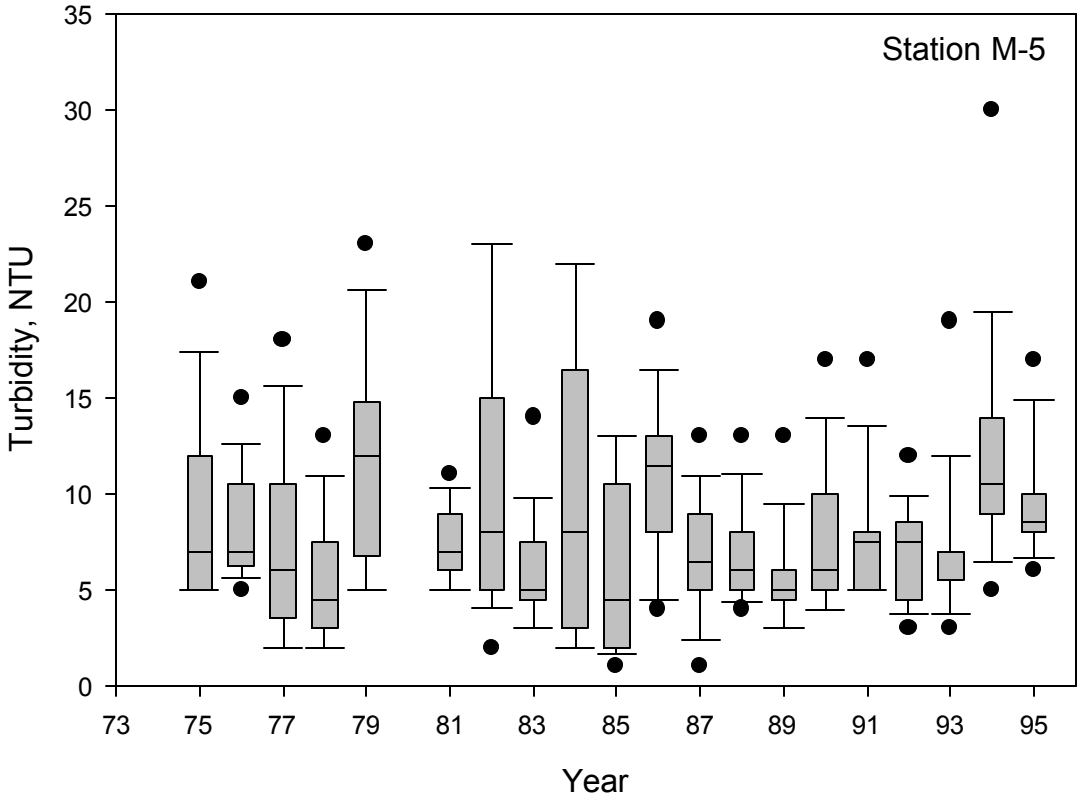

Figure F-7. Turbidity at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

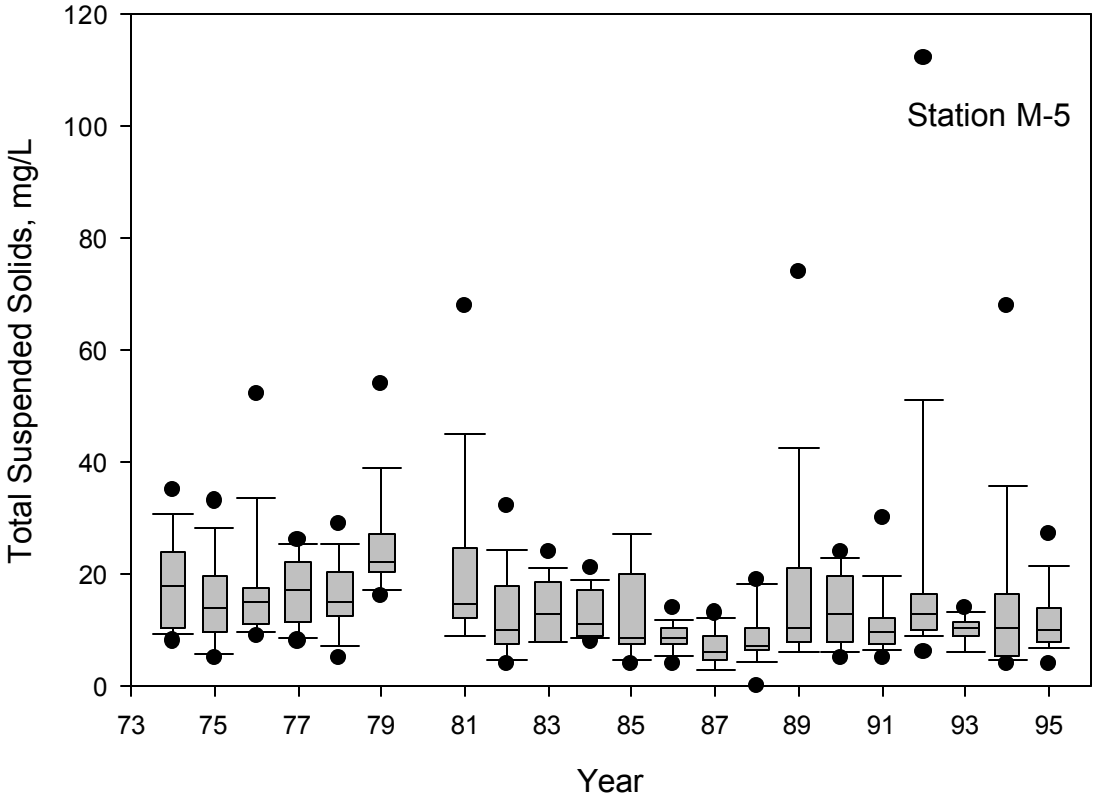

Figure F-8. Total Suspended Solids (TSS) at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1974-1995. Data from MWRDGC.

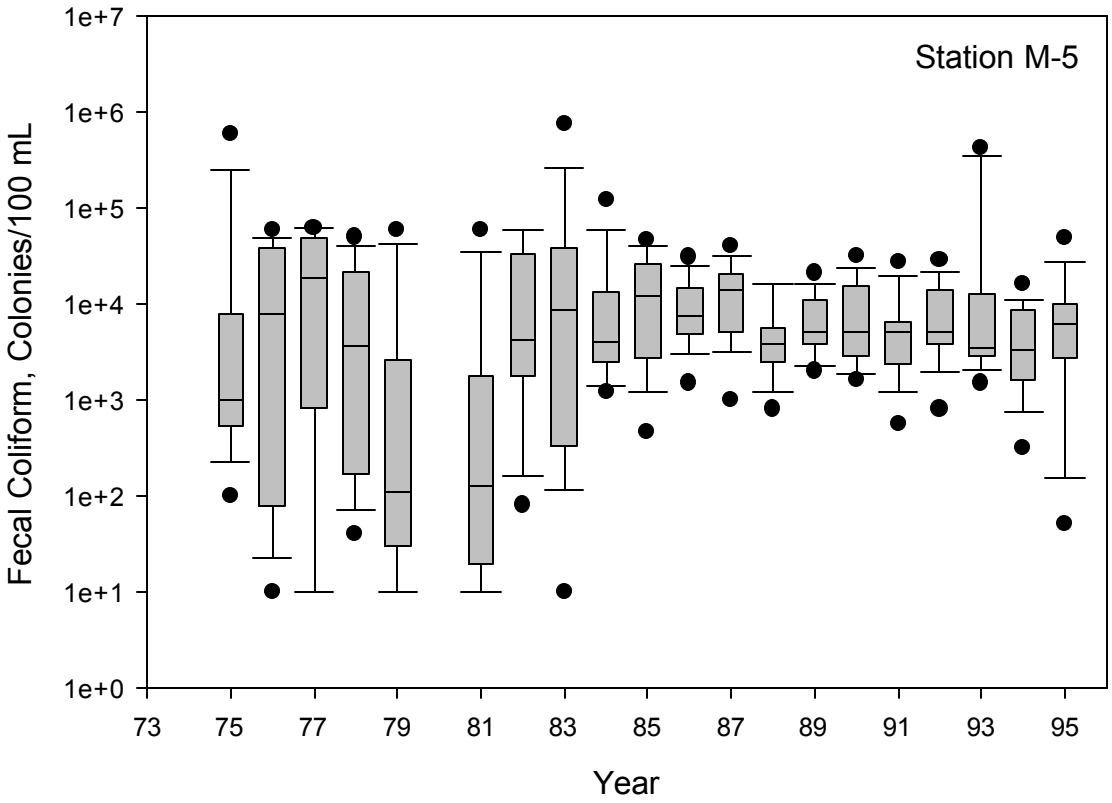

Figure F-9. Fecal Coliform Density at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

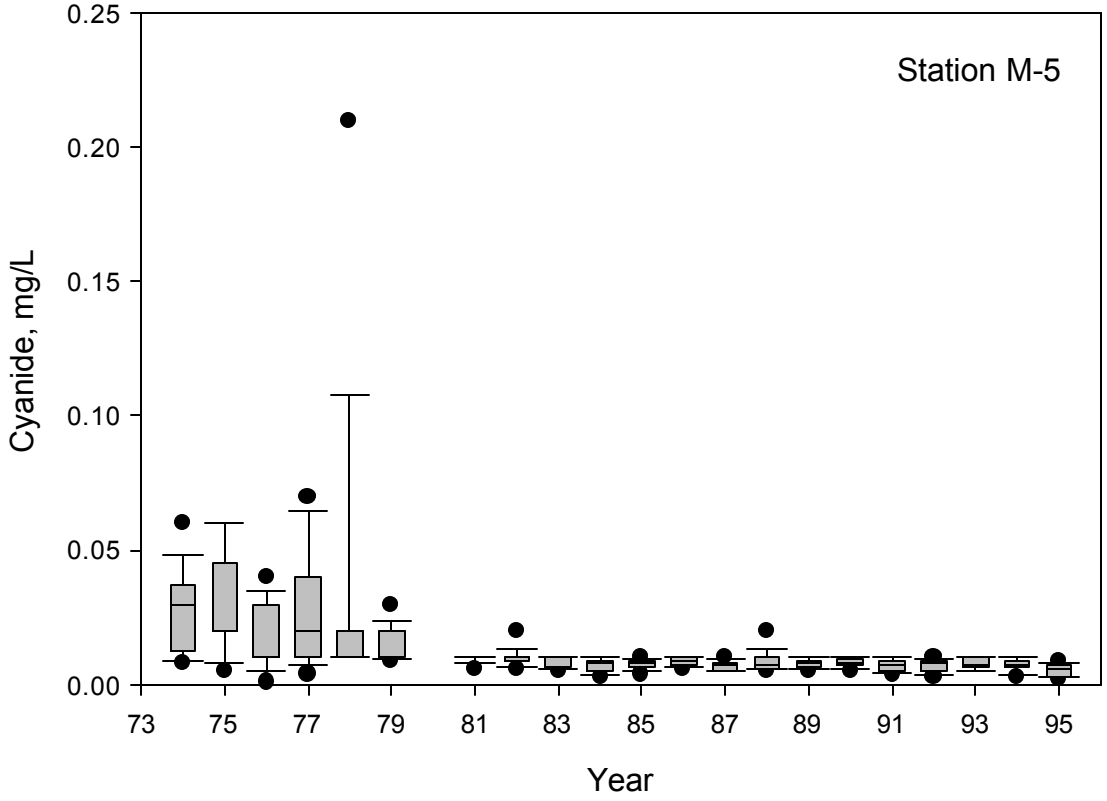

Figure F-10. Cyanide at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1974-1995. Data from MWRDGC.

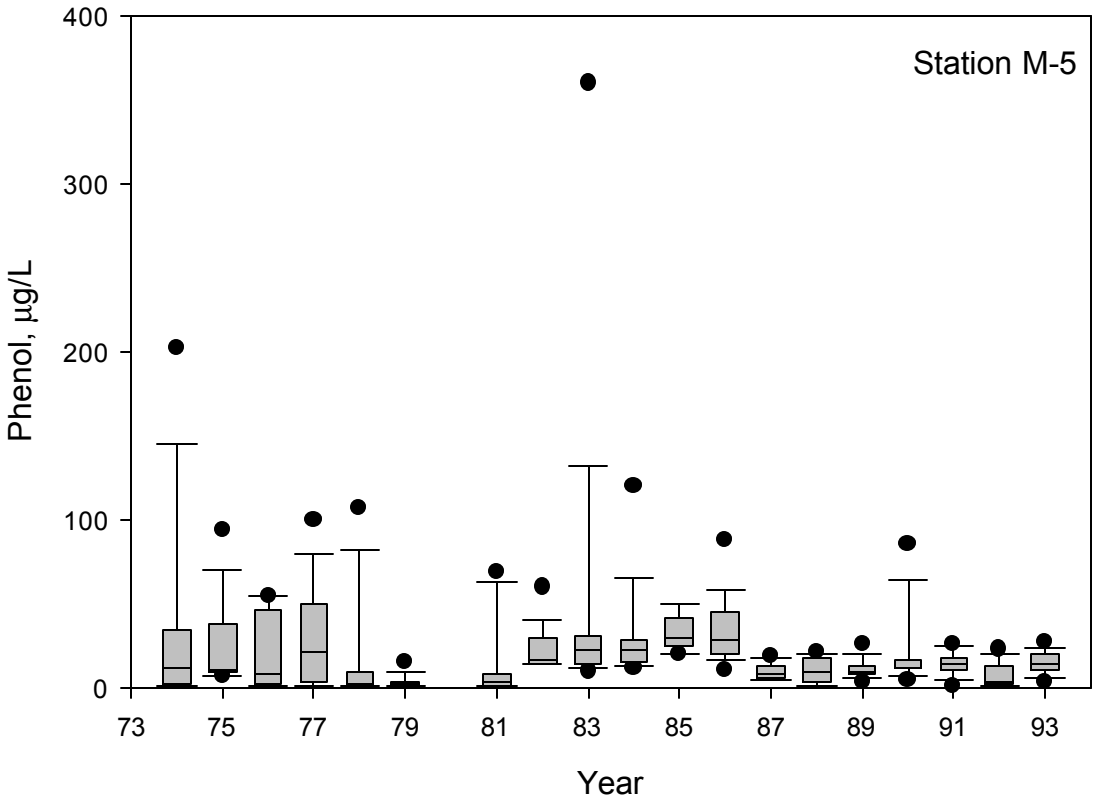

Figure F-11. Phenol at Harlem Ave. (M-5) in the Chicago Sanitary and Ship Canal, 1974-1993. Data from MWRDGC.

Appendix G. Box Plots for Station M-6, Chicago Sanitary and Ship Canal at Route 83

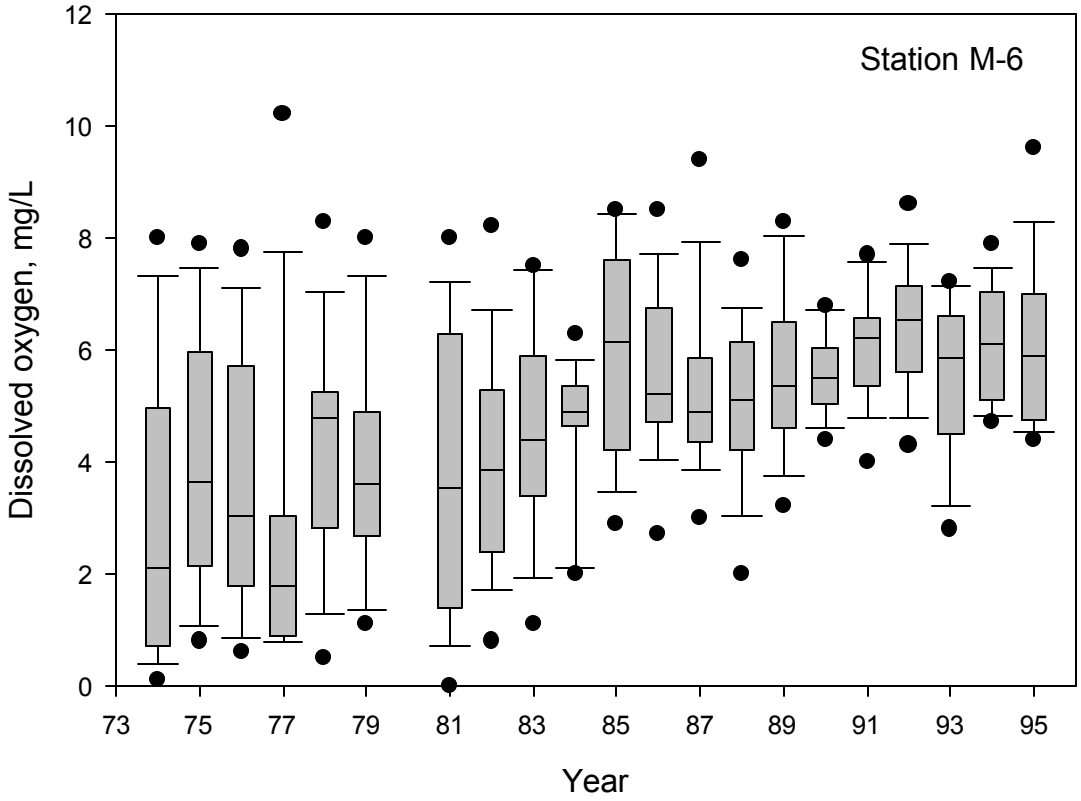

Figure G-1. Dissolved Oxygen (DO) at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1974-1995. Data from MWRDGC.

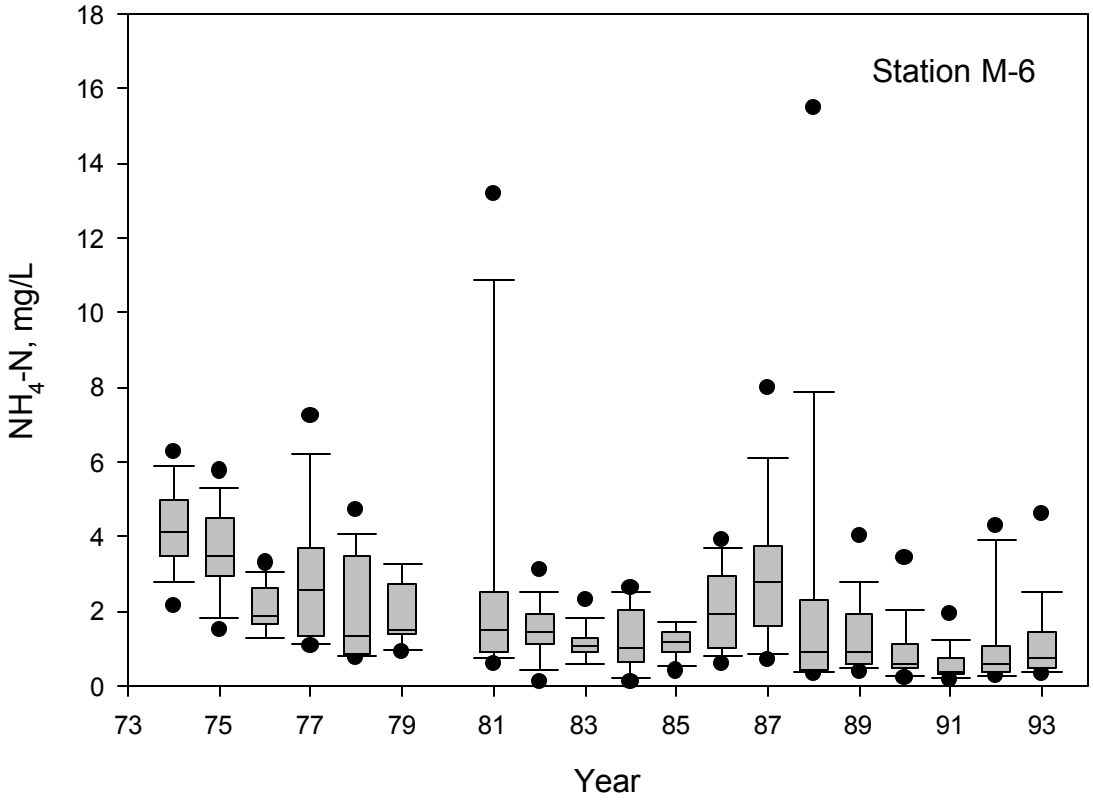

Figure G-1. Ammonia-Nitrogen (NH_4) at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1974-1993. Data from MWRDGC.

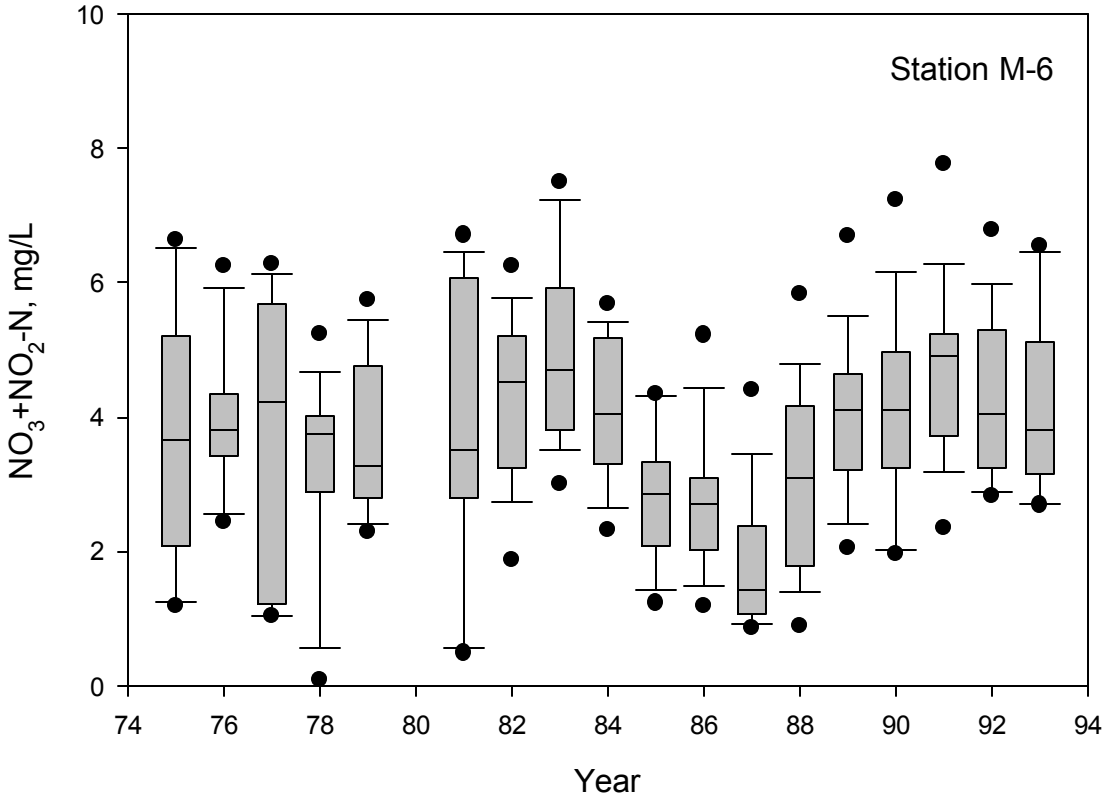

Figure G-3. Nitrate and Nitrite-Nitrogen (NO_3+NO_2-N) at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1975-1993. Data from MWRDGC.

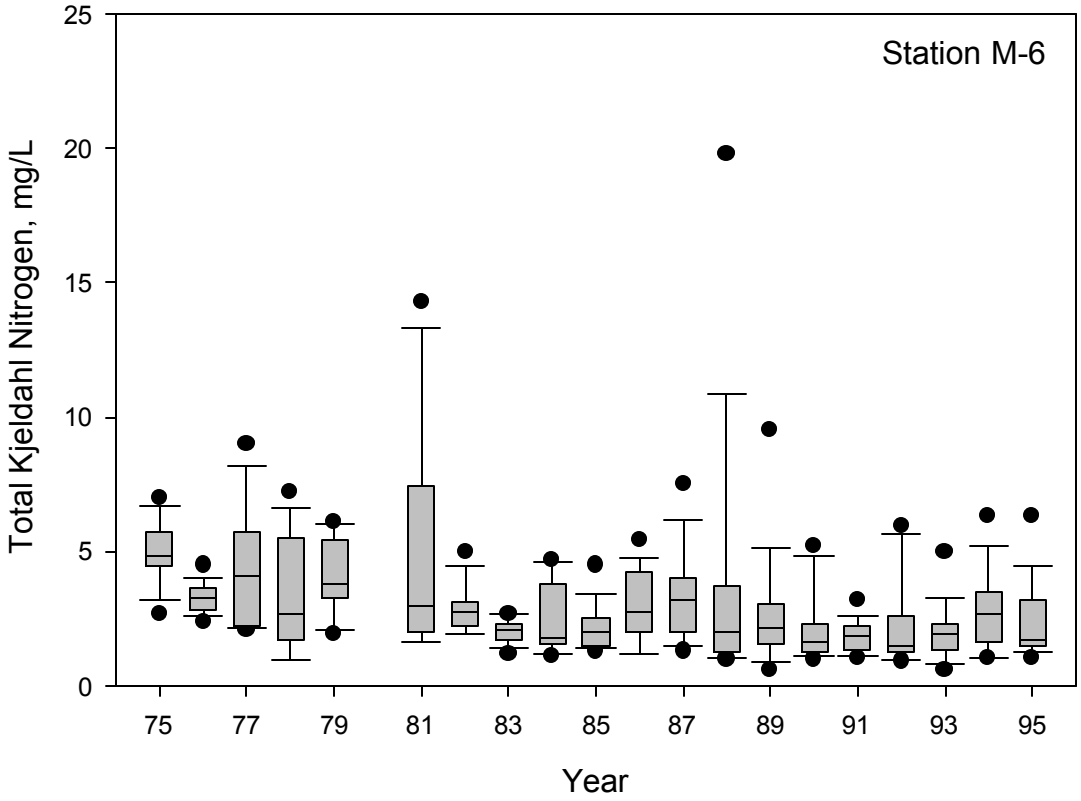

Figure G-4. Total Kjeldahl Nitrogen (TKN) at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

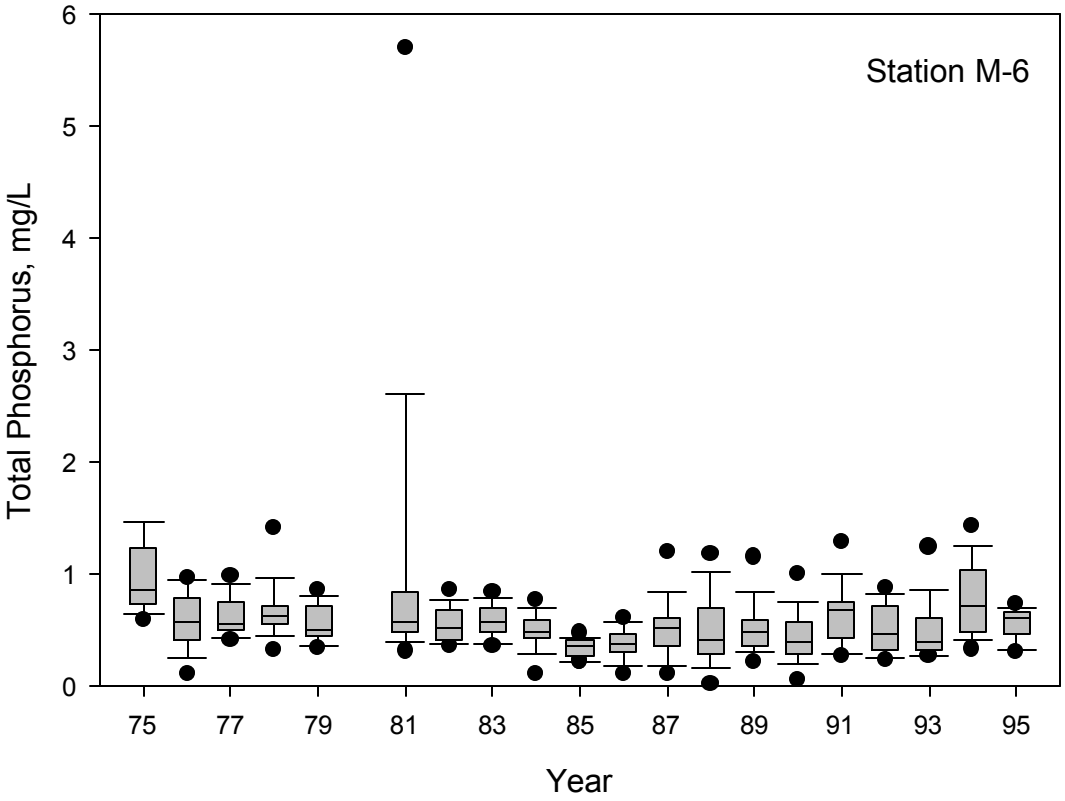

Figure G-5. Total Phosphorus (P) at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

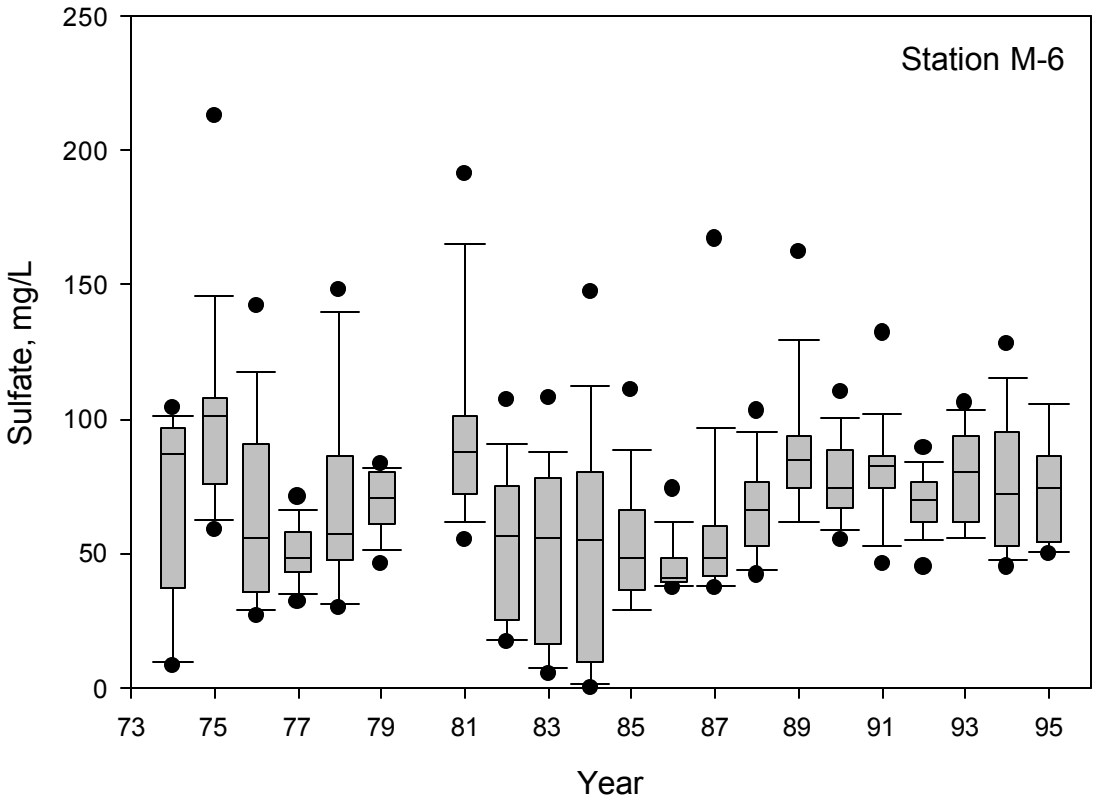

Figure G-6. Sulfate (SO_4) at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

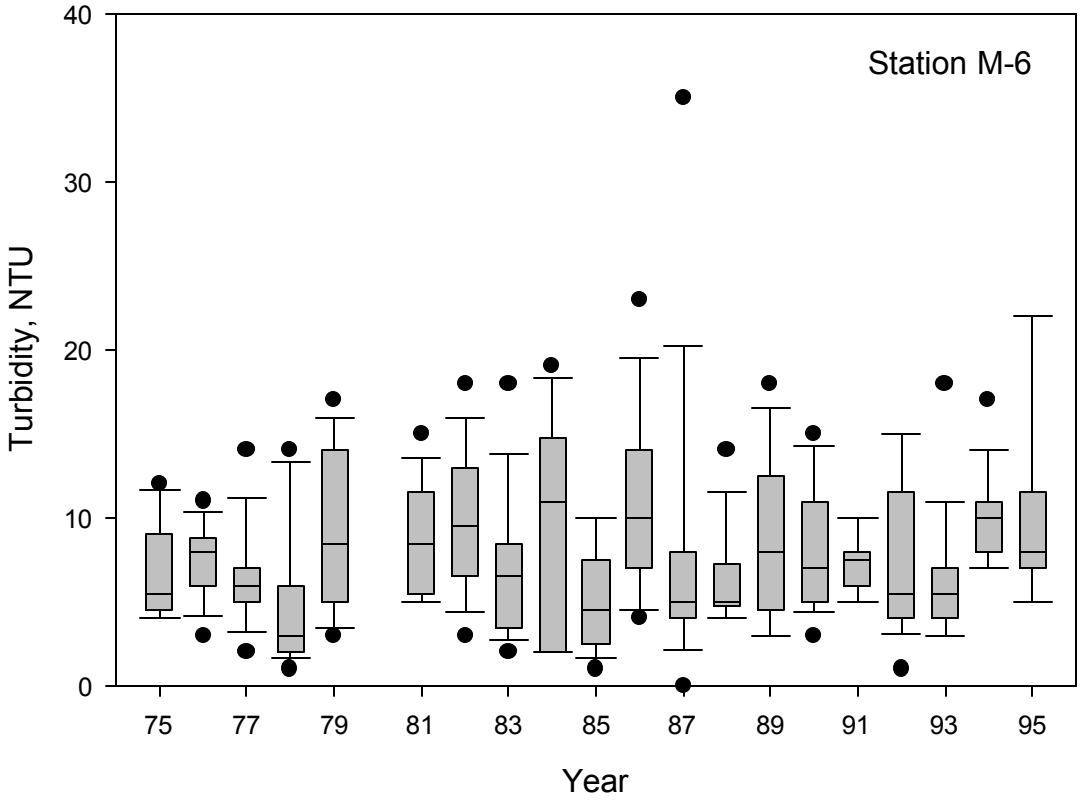

Figure G-7. Turbidity at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

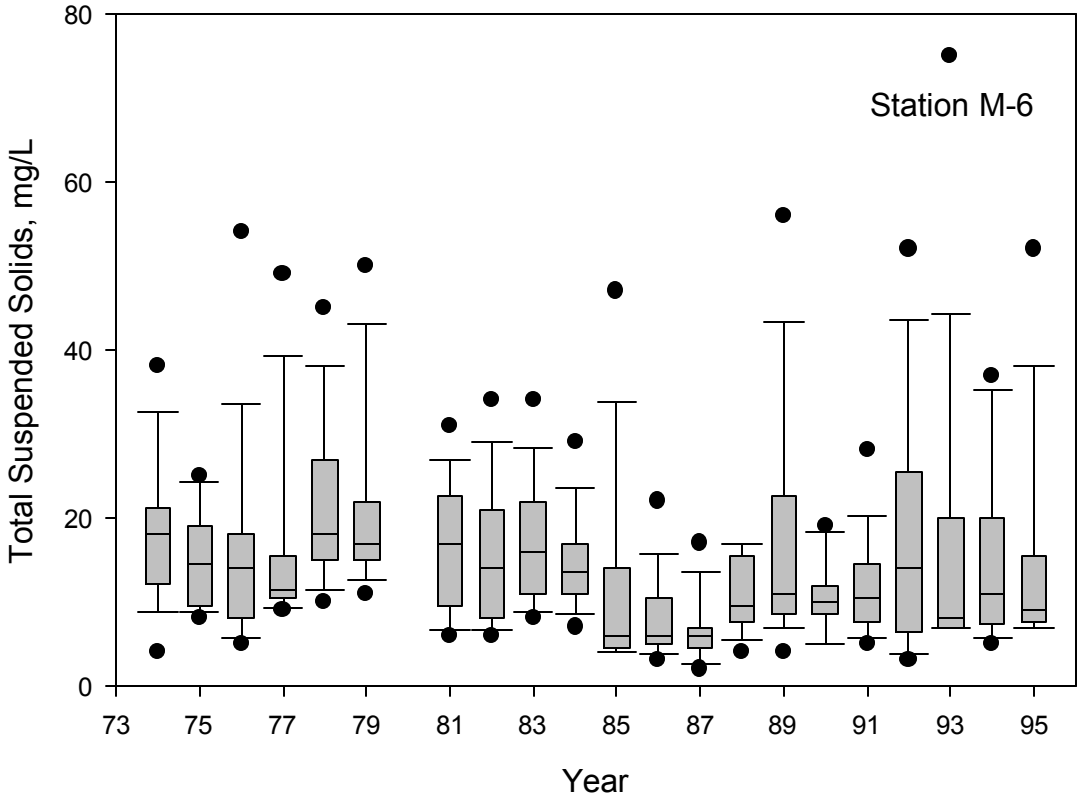

Figure G-8. Total Suspended Solids (TSS) at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1974-1995. Data from MWRDGC.

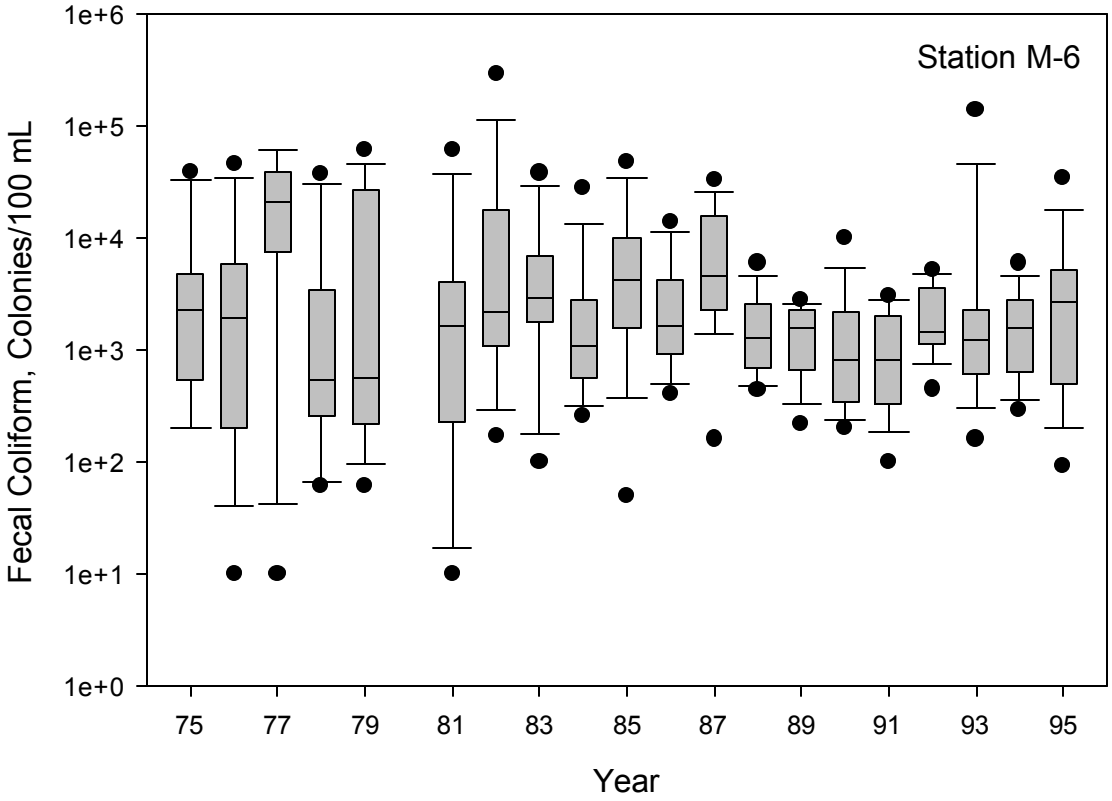

Figure G-9. Fecal Coliform Density at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

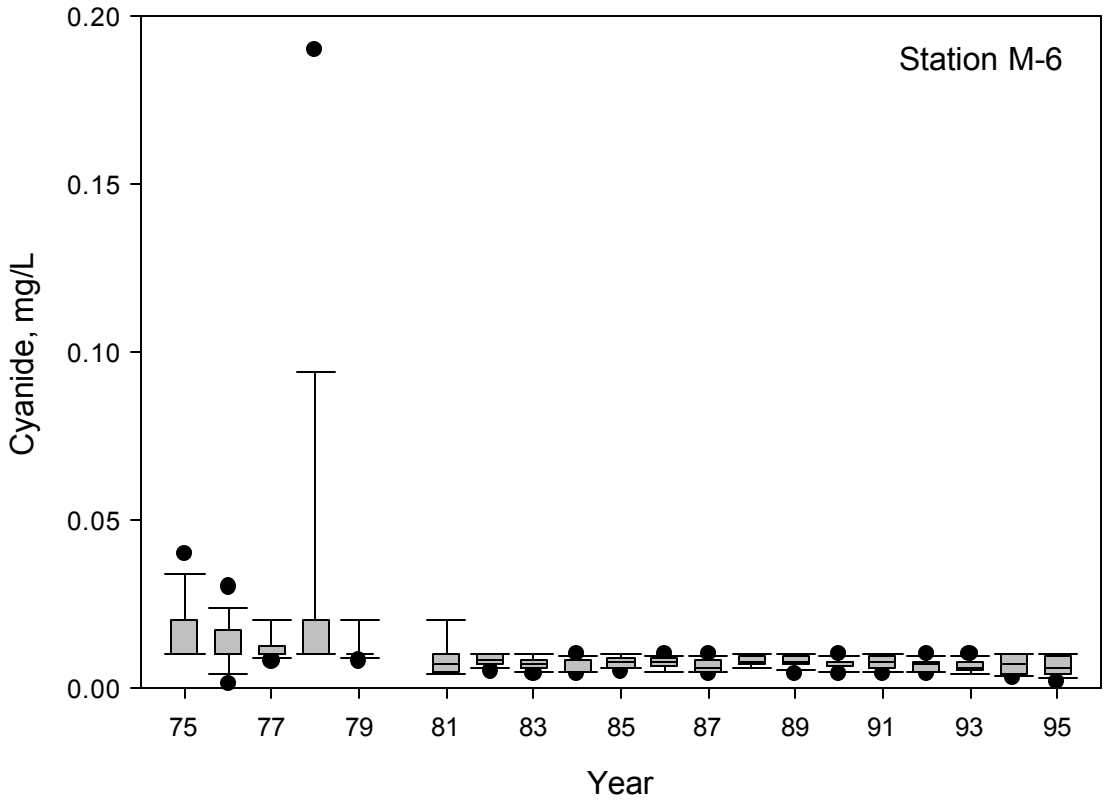

Figure G-10. Cyanide at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1974-1995. Data from MWRDGC.

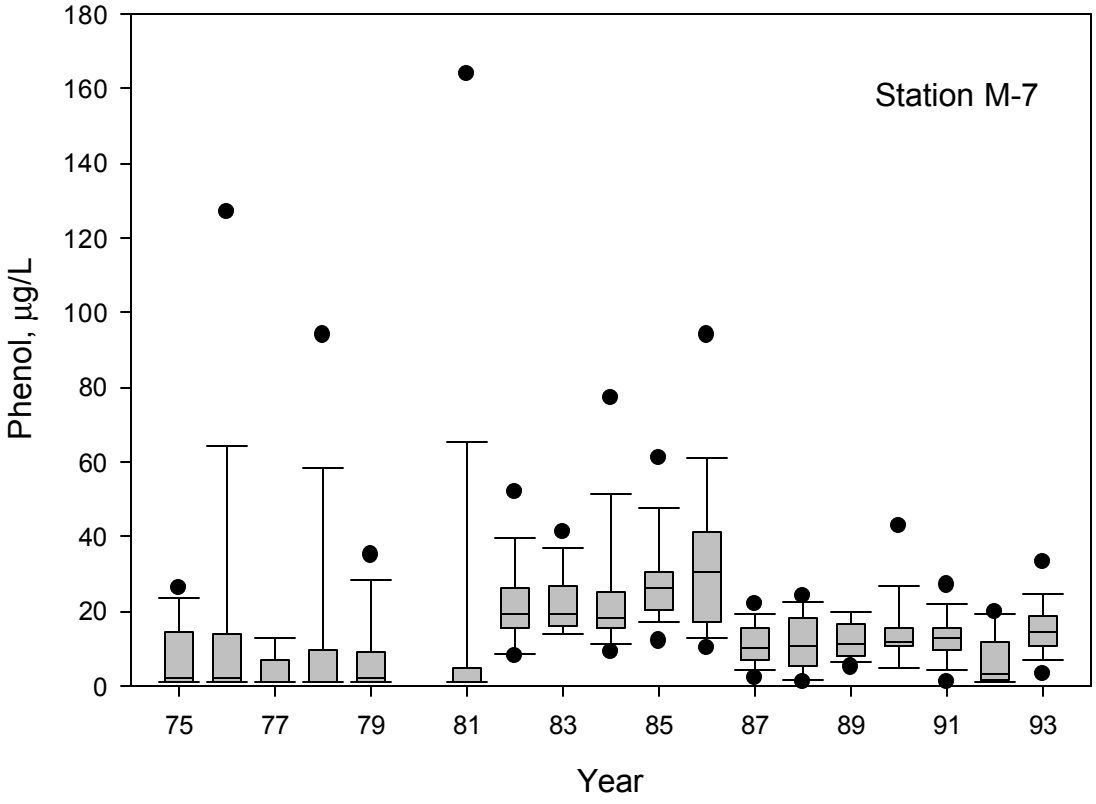

Figure G-11. Phenol at Route 83 (M-6) in the Chicago Sanitary and Ship Canal, 1975-1995. Data from MWRDGC.

Appendix H. Box Plots for Station M-7, Cal-Sag Channel at Ashland Ave.

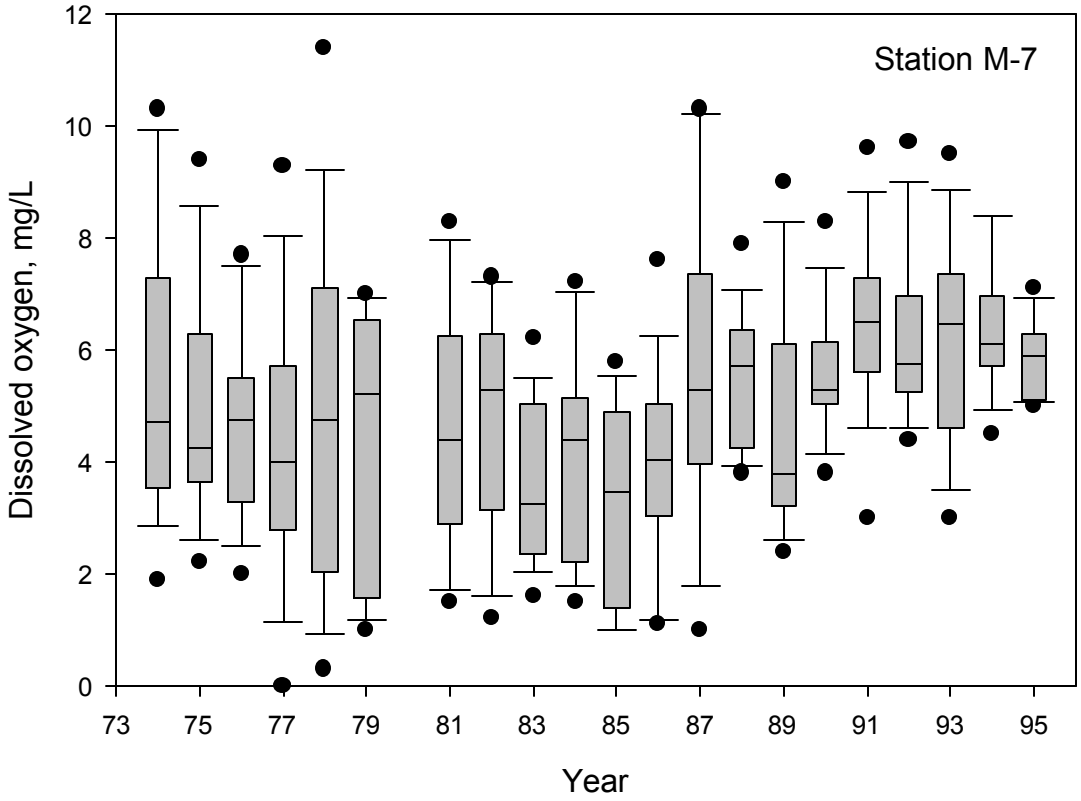

Figure H-1. Dissolved Oxygen (DO) at Ashland Ave. (M-7) in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

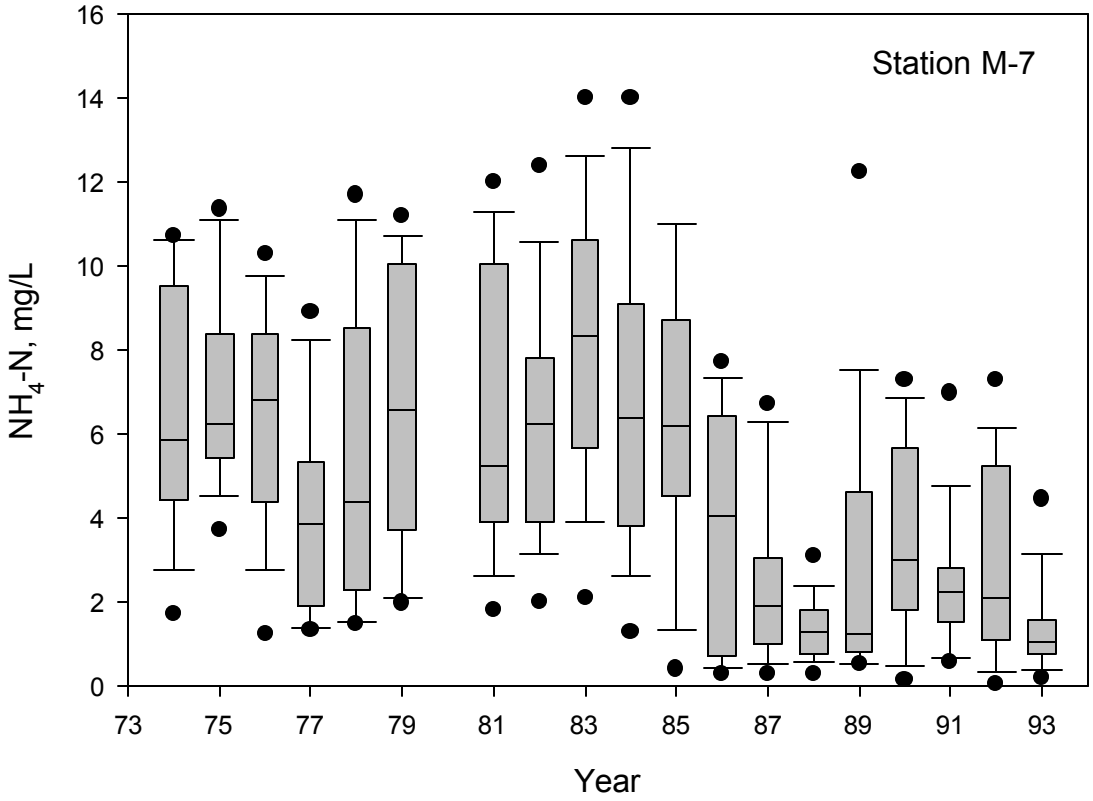

Figure H-2. Ammonia-Nitrogen (NH_4) at Ashland Ave. (M-7) in the Cal-Sag Canal, 1974-1993. Data from MWRDGC.

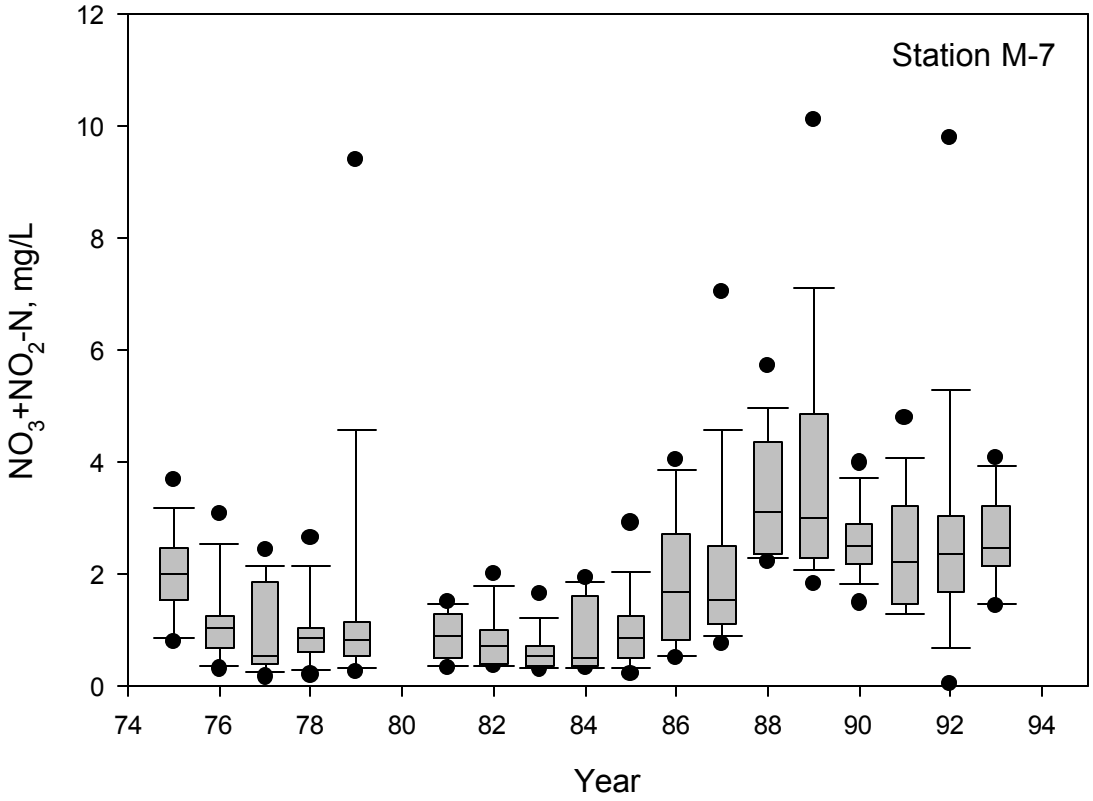

Figure H-3. Nitrate and Nitrite-Nitrogen (NO_3+NO_2-N) at Ashland Ave. (M-7) in the Cal-Sag Canal, 1975-1993. Data from MWRDGC.

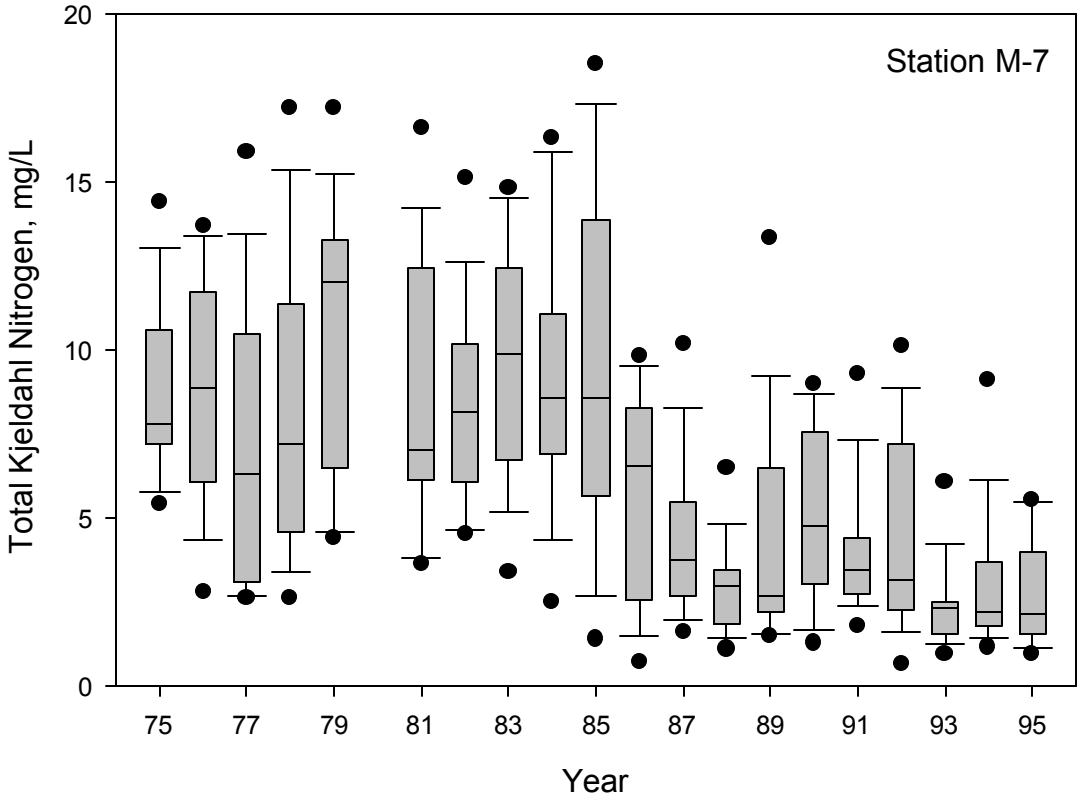

Figure H-4. Total Kjeldahl Nitrogen (TKN) at Ashland Ave. (M-7) in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

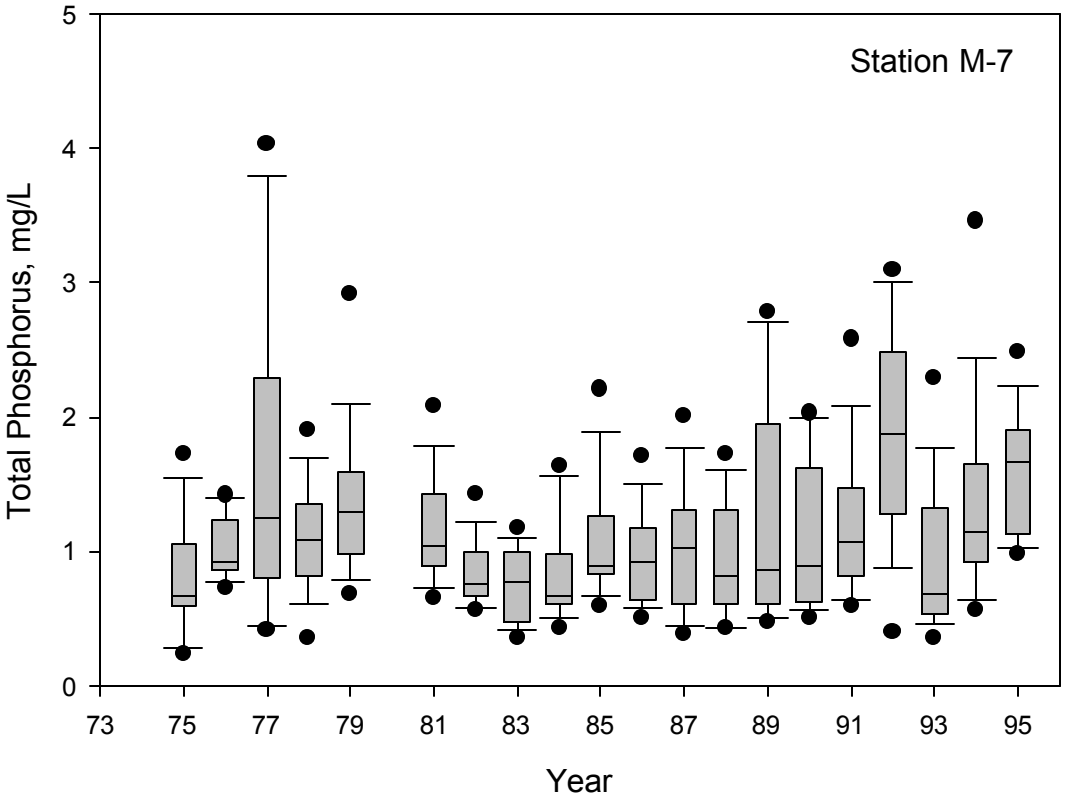

Figure H-5. Total Phosphorus (P) at Ashland Ave. (M-7) in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

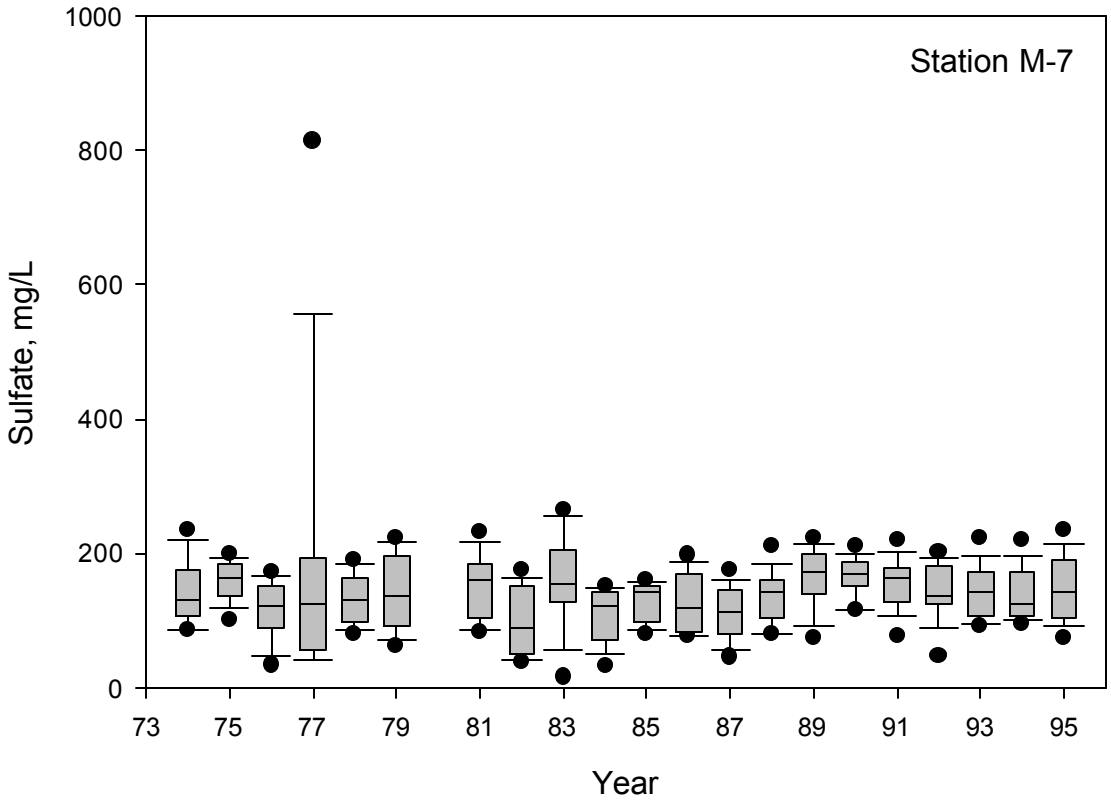

Figure H-6. Sulfate (SO_4) at Ashland Ave. (M-7) in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

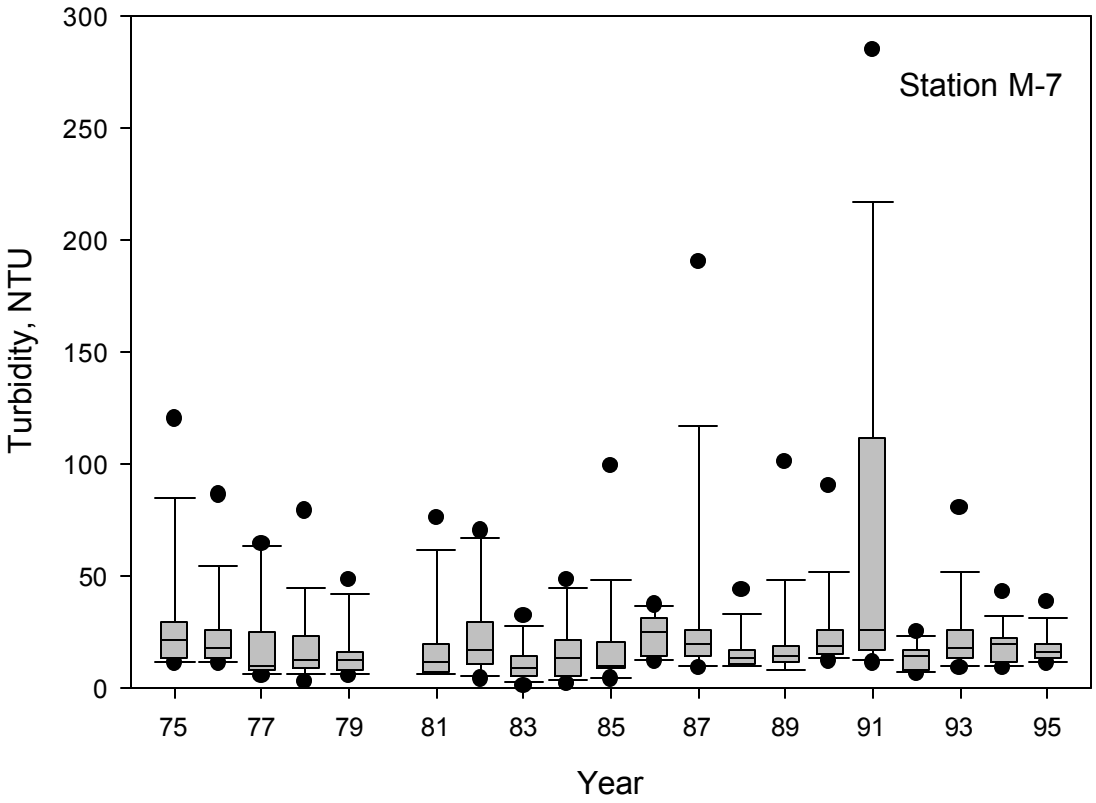

Figure H-7. Turbidity at Ashland Ave. (M-7) in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

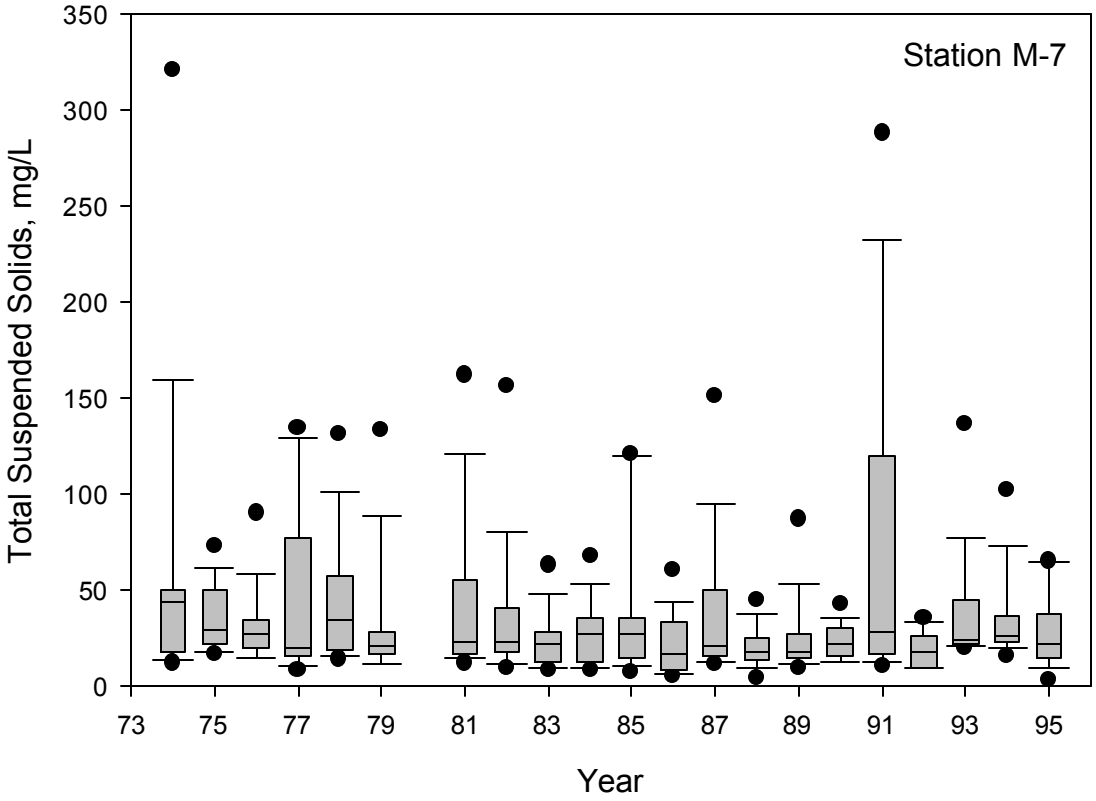

Figure H-8. Total Suspended Solids (TSS) at Ashland Ave. (M-7) in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

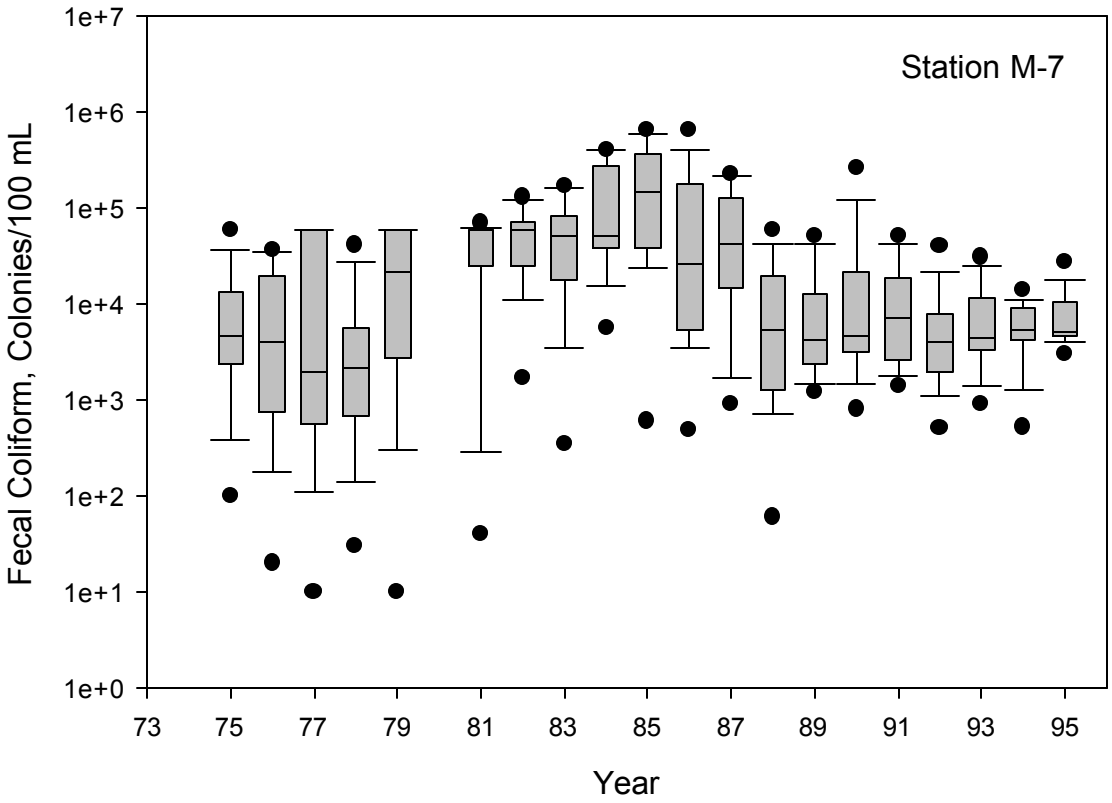

Figure H-9. Fecal Coliform Density at Ashland Ave. (M-7) in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

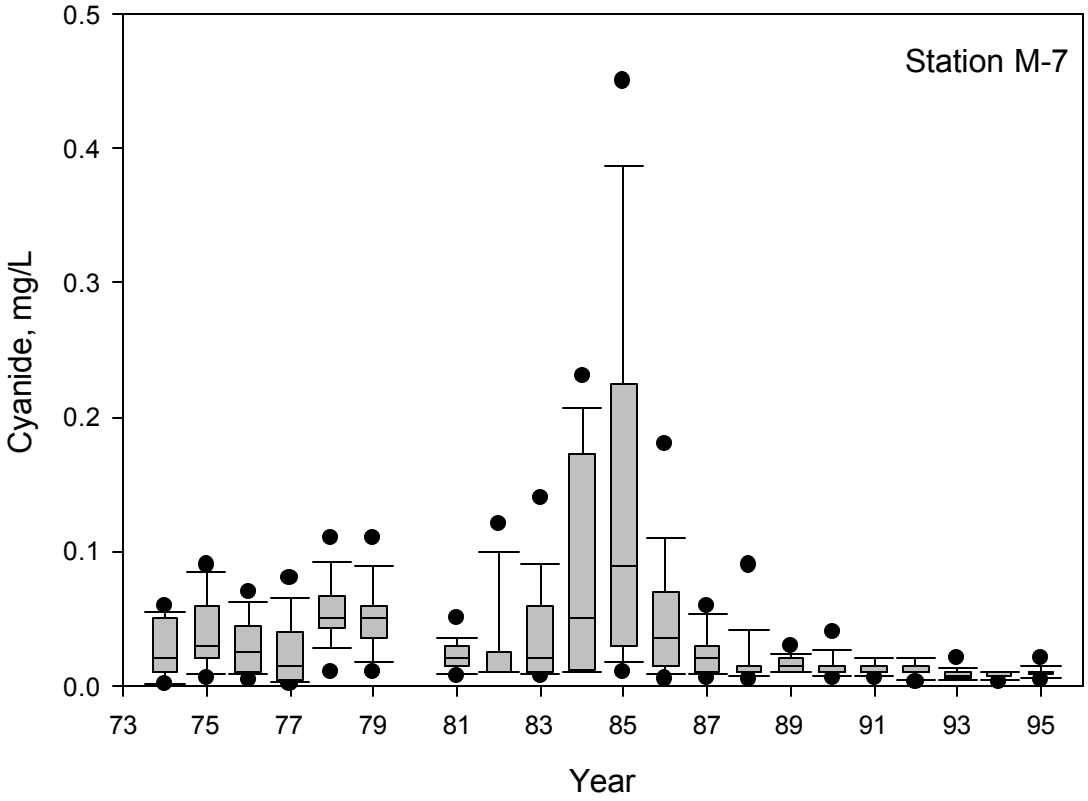

Figure H-10. Cyanide at Ashland Ave. (M-7) in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

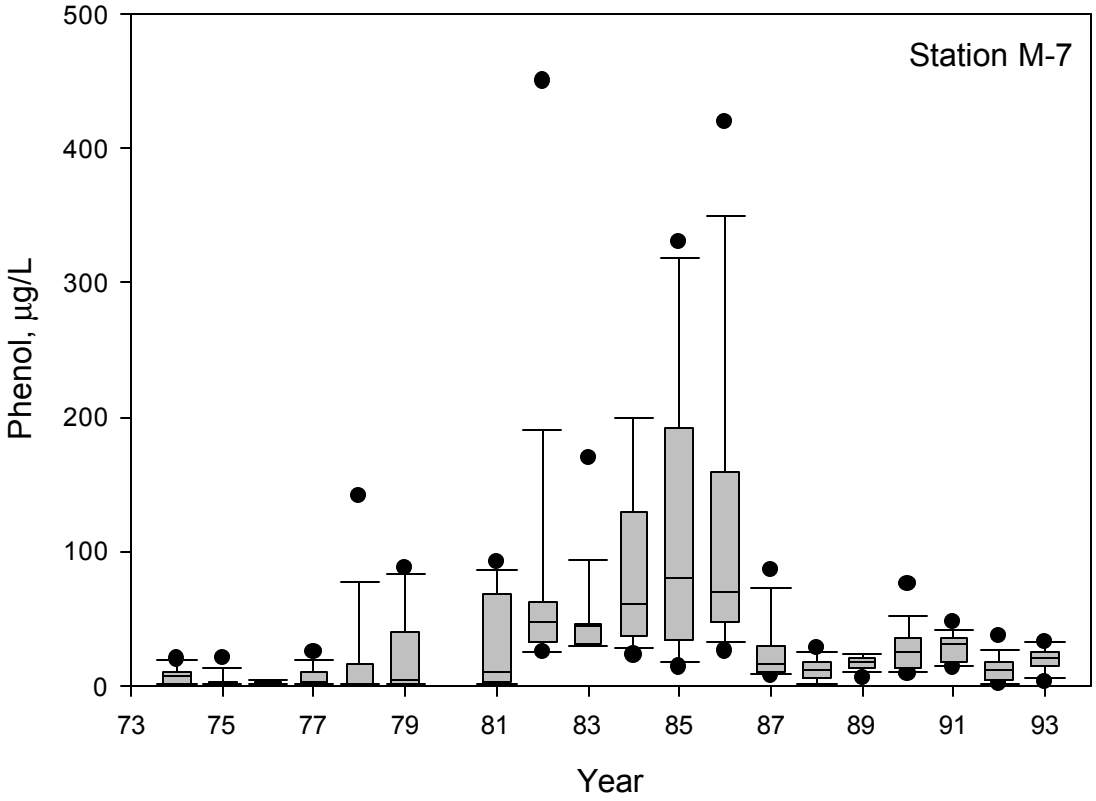

Figure H-11. Phenol at Ashland Ave. (M-7) in the Cal-Sag Canal, 1974-1993. Data from MWRDGC.

Appendix I. Box Plots for Station M-8, Cal-Sag Channel at Cicero Ave.

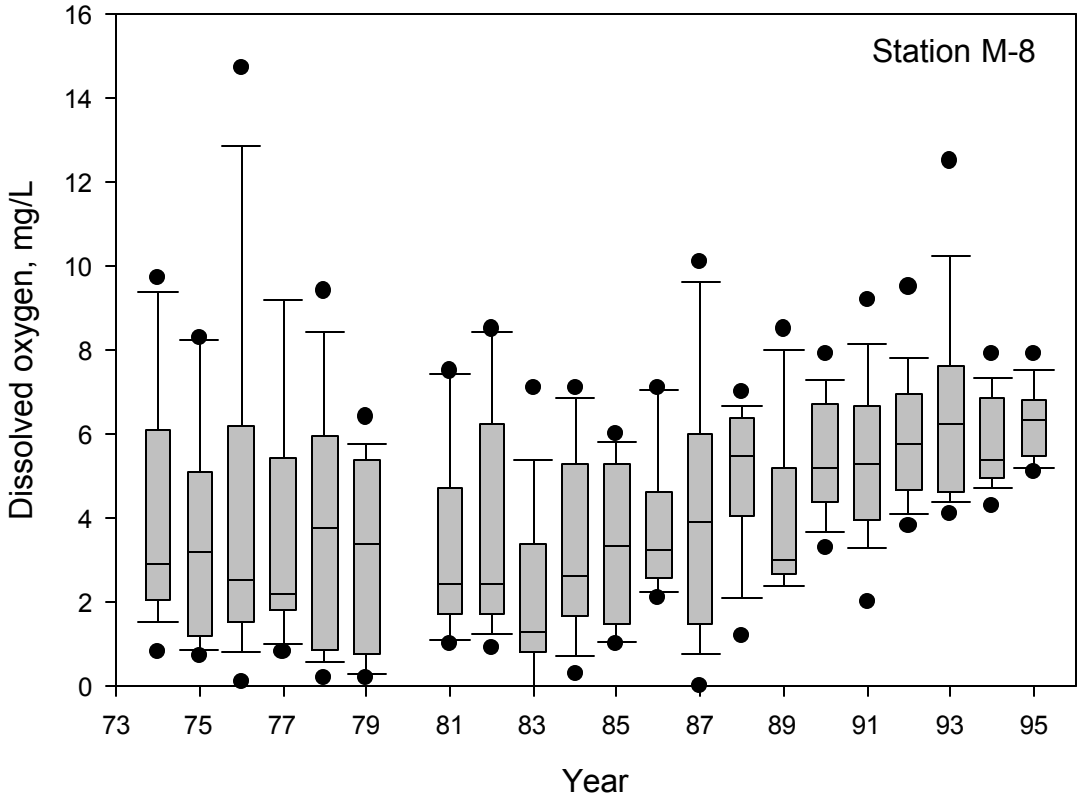

Figure I-1. Dissolved Oxygen (DO) at Cicero Ave. (M-8)
in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

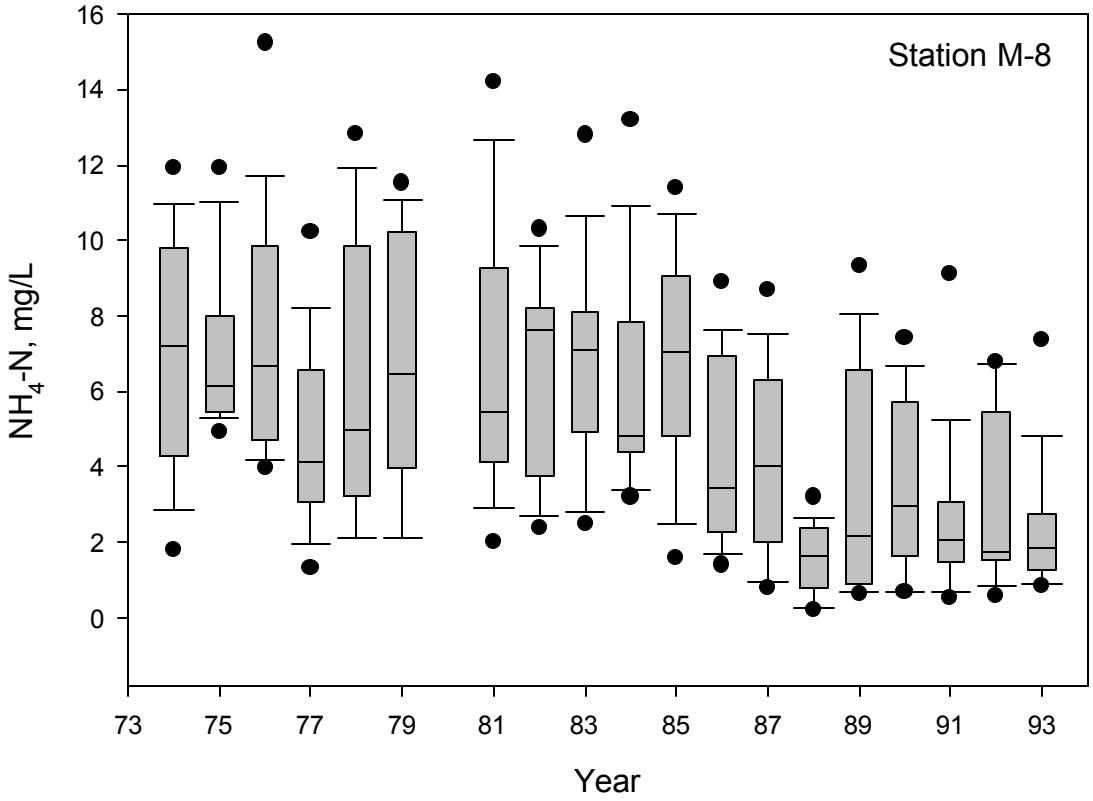

Figure I-2. Ammonia-Nitrogen (NH_4) at Cicero Ave. (M-8) in the Cal-Sag Canal, 1974-1993. Data from MWRDGC.

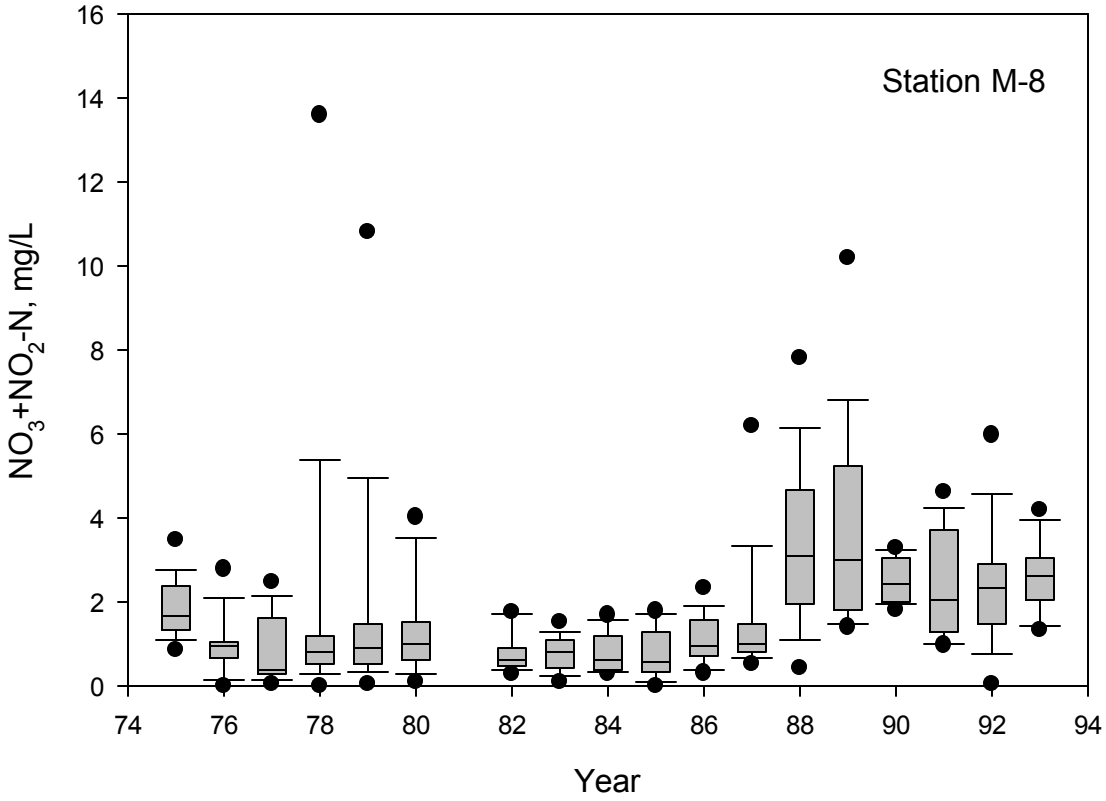

Figure I-3. Nitrate and Nitrite-Nitrogen (NO_3+NO_2-N) at Cicero Ave. (M-8) in the Cal-Sag Canal, 1975-1993. Data from MWRDGC.

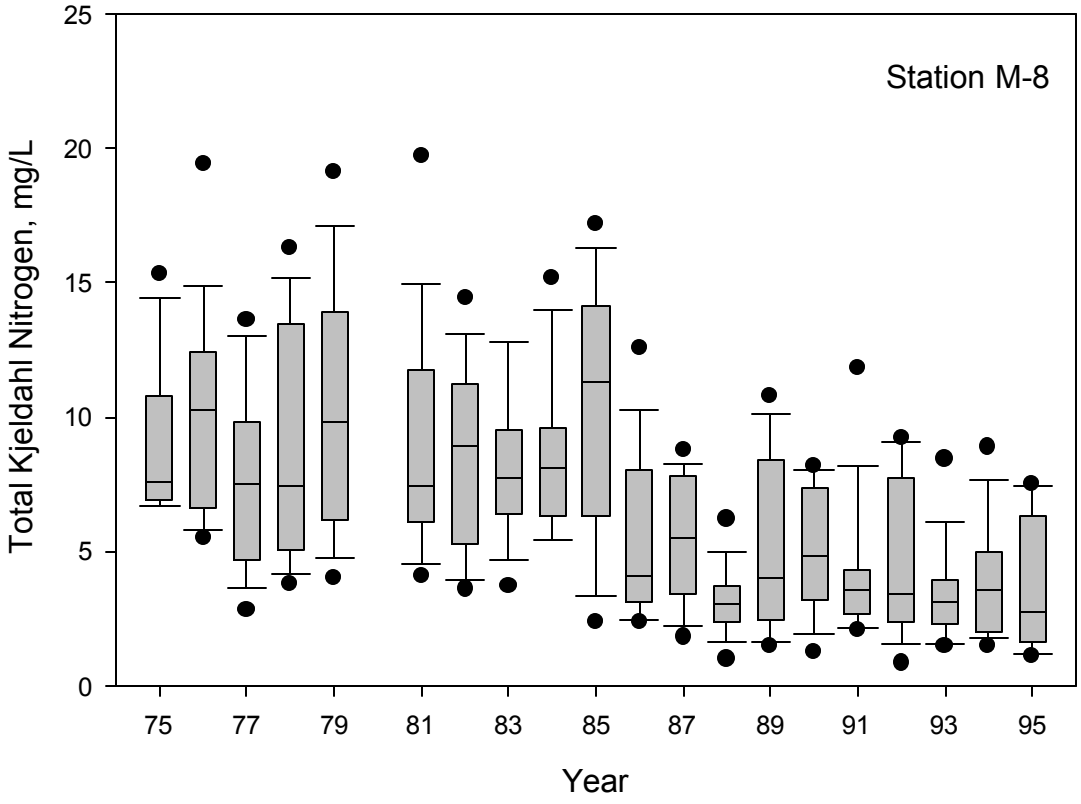

Figure I-4. Total Kjeldahl Nitrogen (TKN) at Cicero Ave. (M-8)
in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

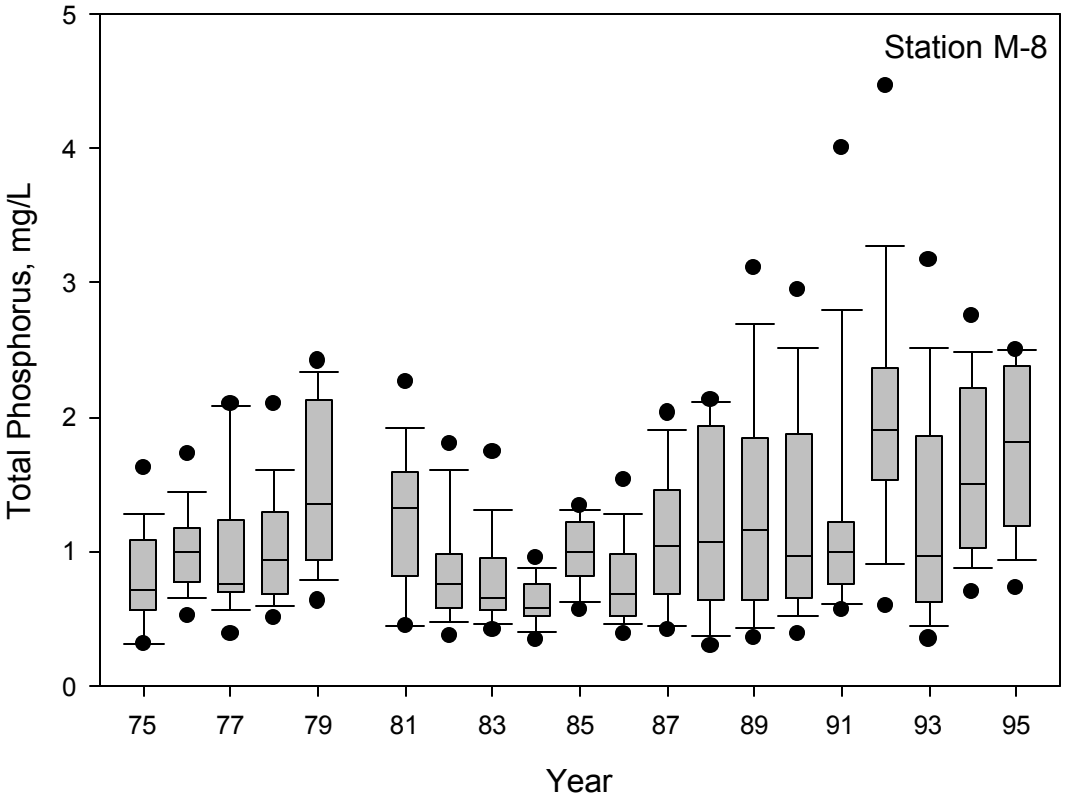

Figure I-5. Total Phosphorus (P) at Cicero Ave. (M-8) in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

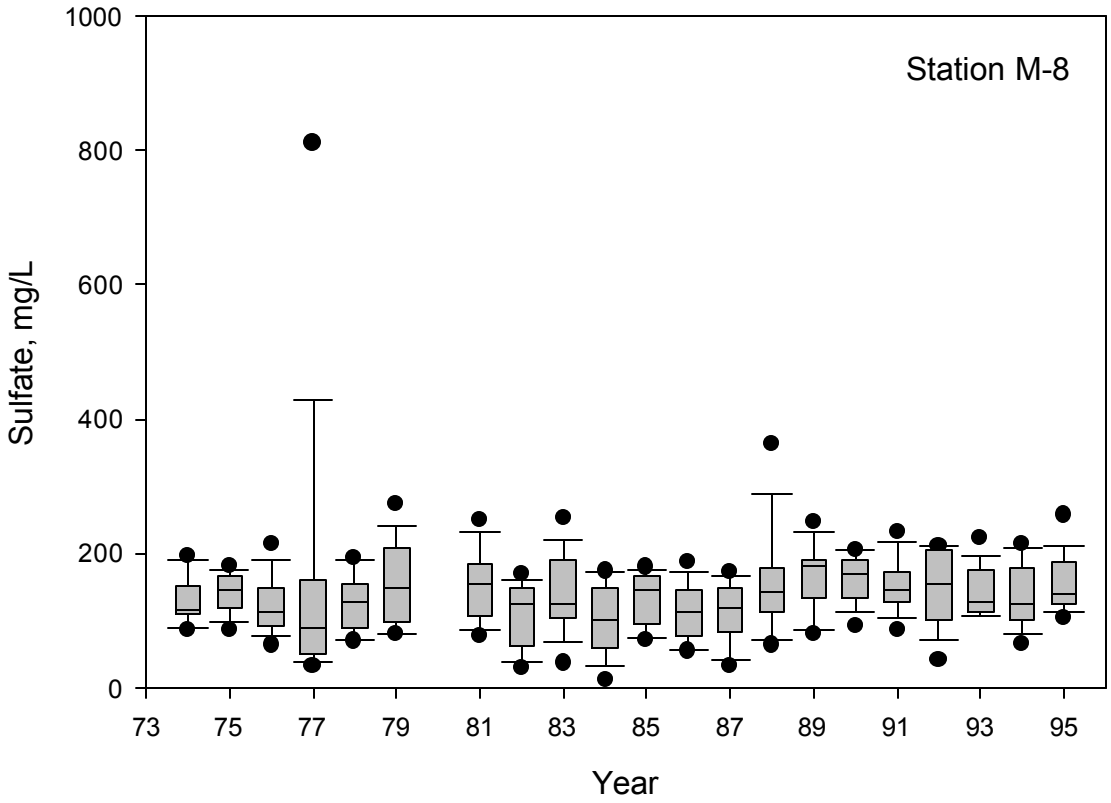

Figure I-6. Sulfate (SO_4) at Cicero Ave. (M-8) in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

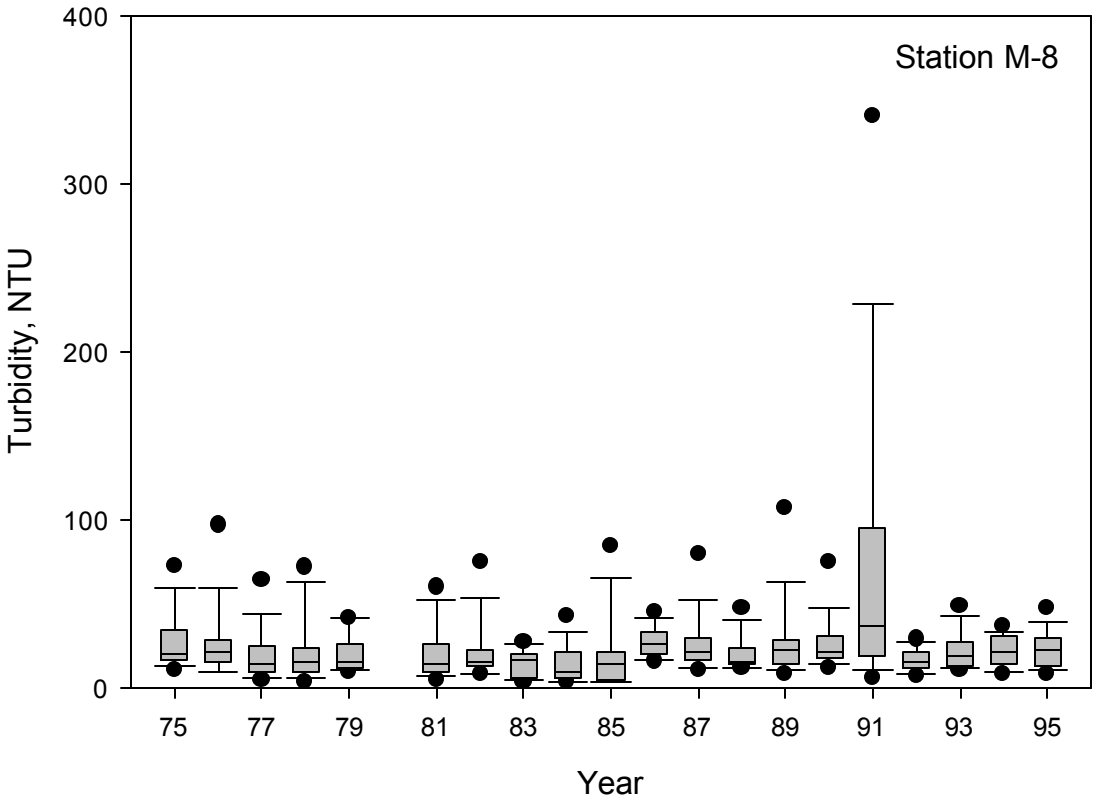

Figure I-7. Turbidity at Cicero Ave. (M-8) in the
Cal-Sag Canal, 1975-1995. Data from MWRDGC.

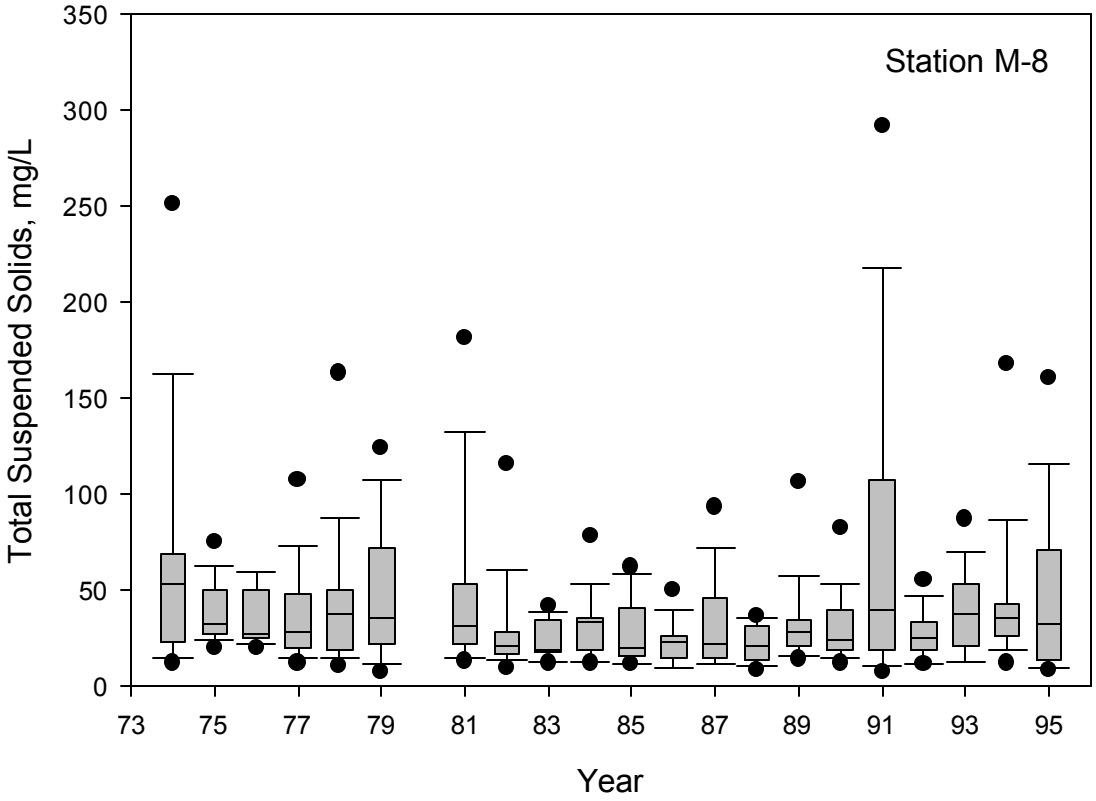

Figure I-8. Total Suspended Solids (TSS) at Cicero Ave. (M-8)
in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

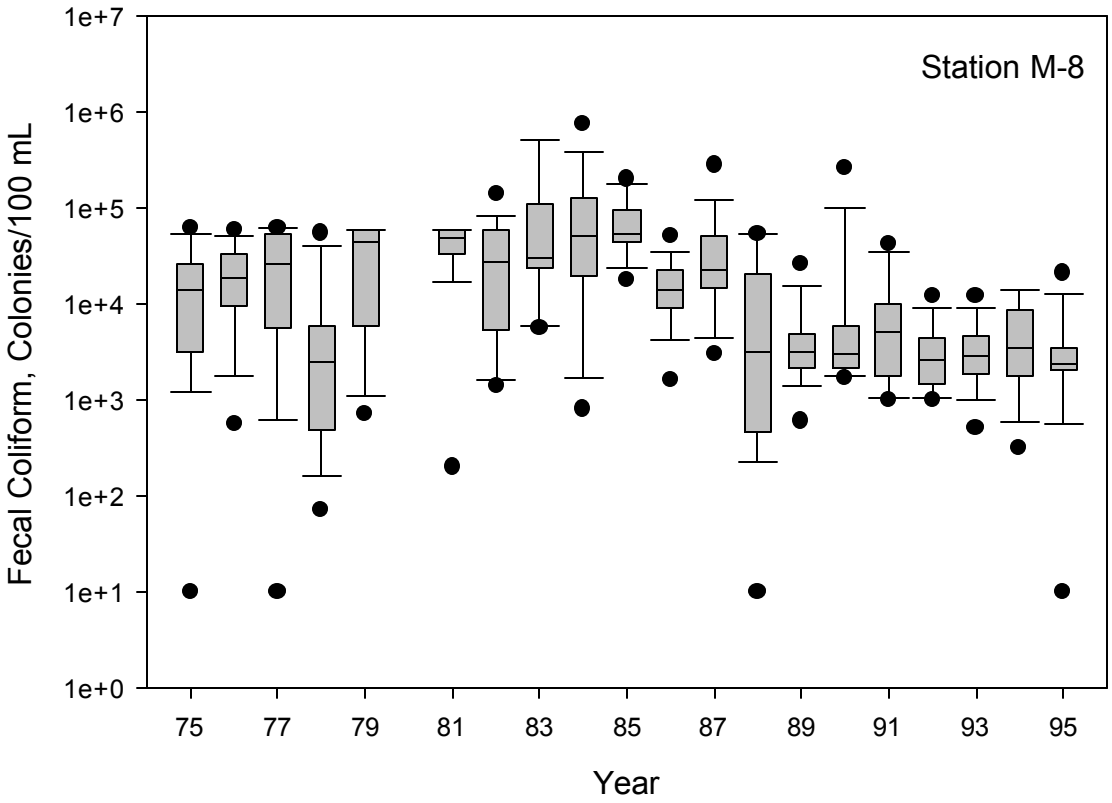

Figure I-9. Fecal Coliform Density at Cicero Ave. (M-8) in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

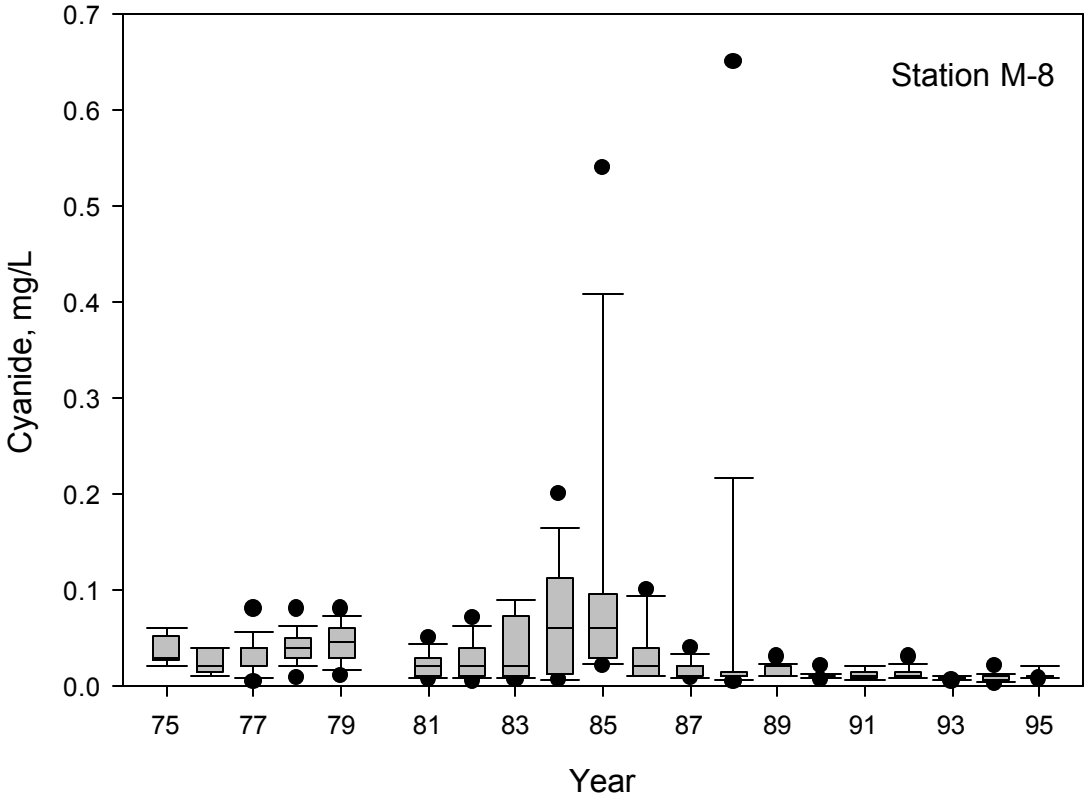

Figure I-10. Cyanide at Cicero Ave. (M-8) in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

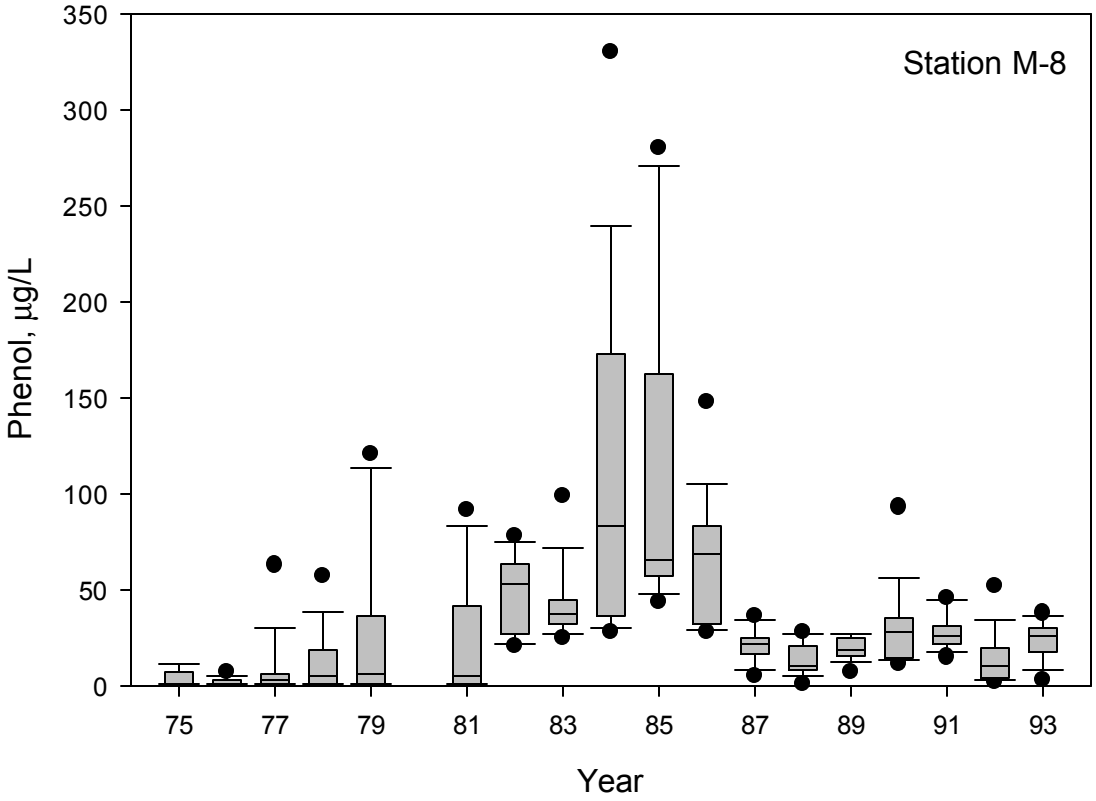

Figure I-11. Phenol at Cicero Ave. (M-8) in the
Cal-Sag Canal, 1975-1993. Data from MWRDGC.

Appendix J. Box Plots for Station M-9, Cal-Sag Channel at Route 83

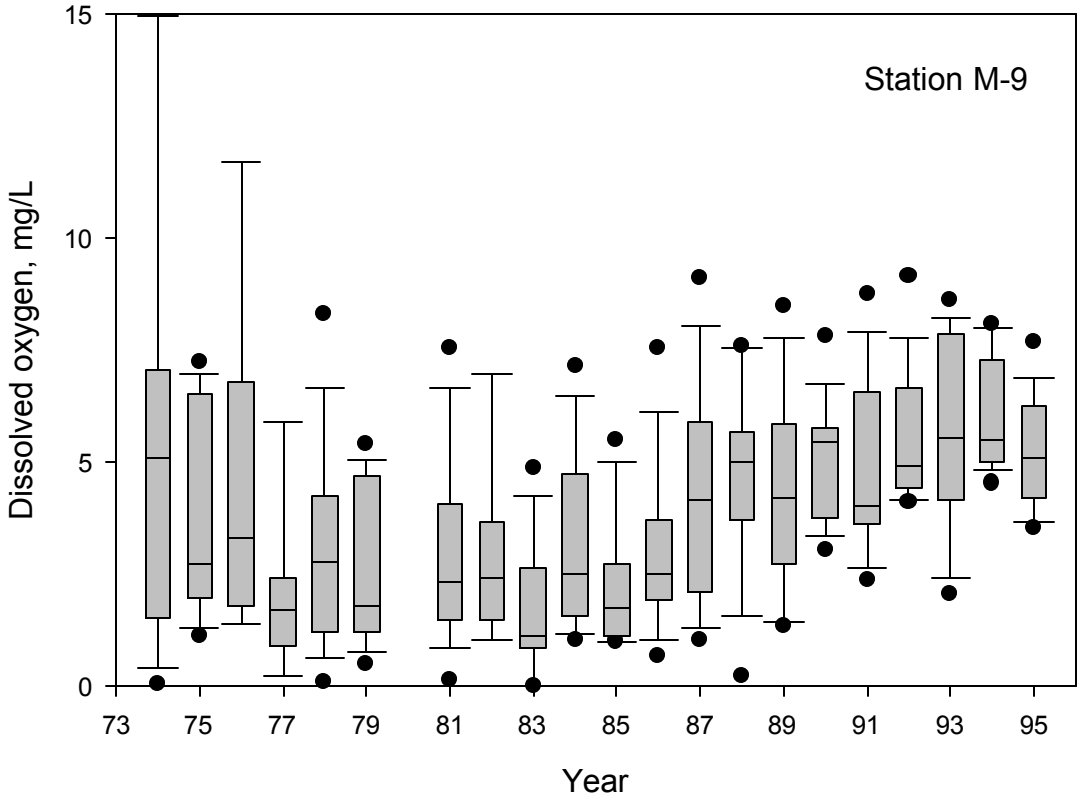

Figure J-1. Dissolved Oxygen (DO) at Route 83 (M-9)
in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

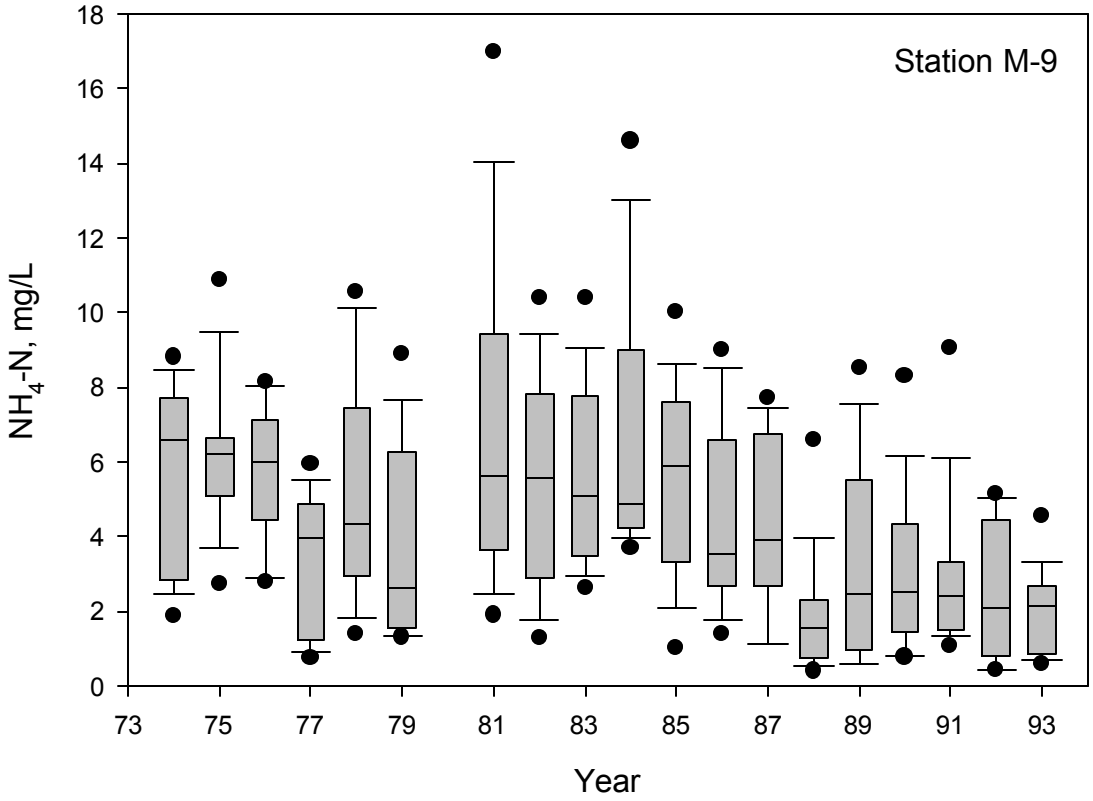

Figure J-2. Ammonia-Nitrogen (NH_4-N) at Route 83 (M-9)
in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

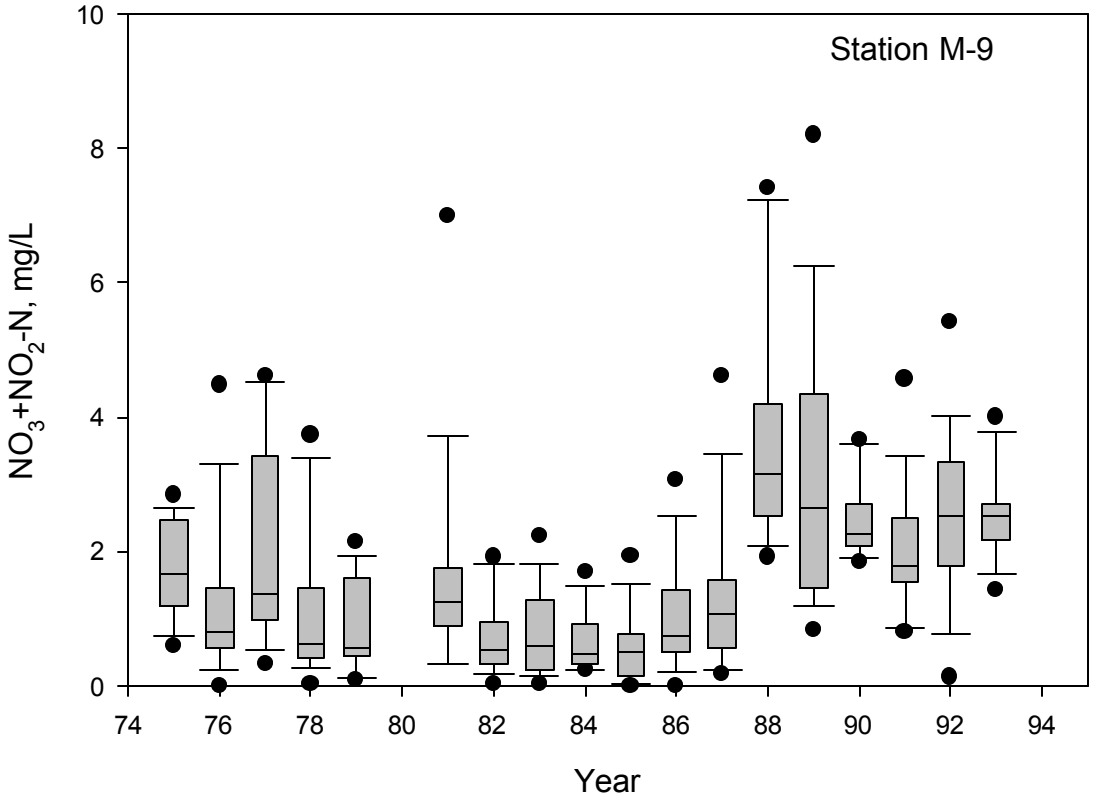

Figure J-3. Nitrate and Nitrite-Nitrogen (NO_3+NO_2-N) at Route 83 (M-9) in the Cal-Sag Canal, 1975-1993. Data from MWRDGC.

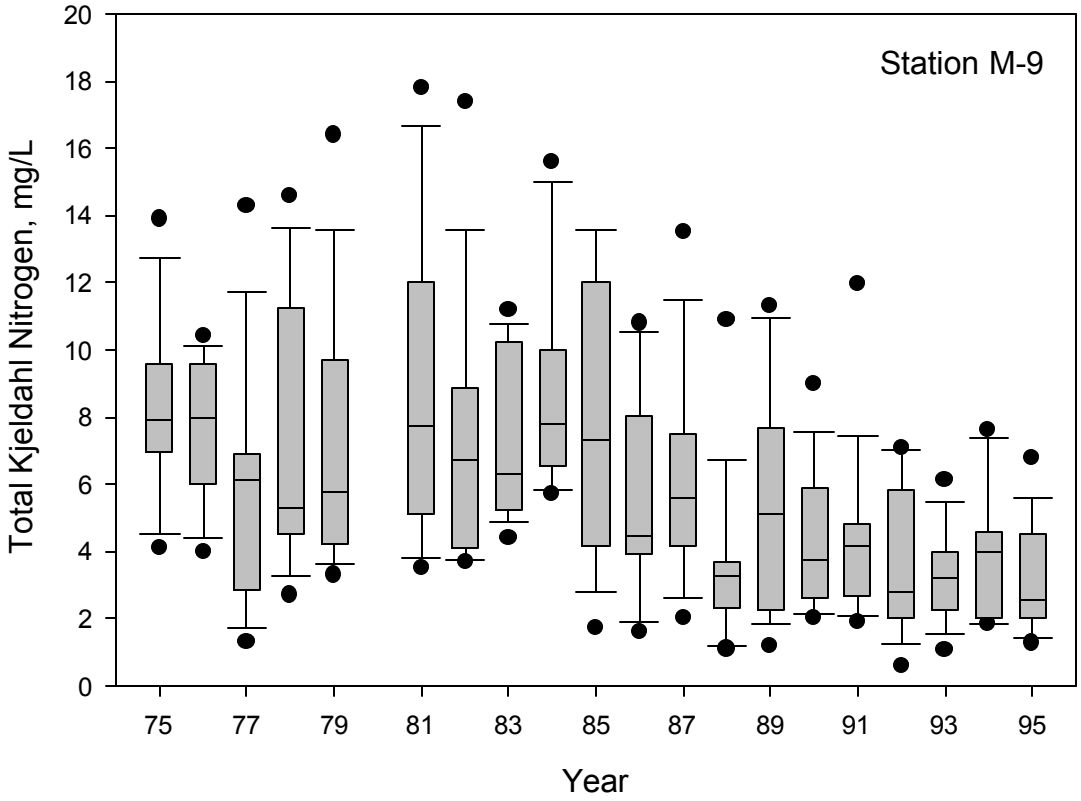

Figure J-4. Total Kjeldahl Nitrogen (TKN) at Route 83 (M-9)
in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

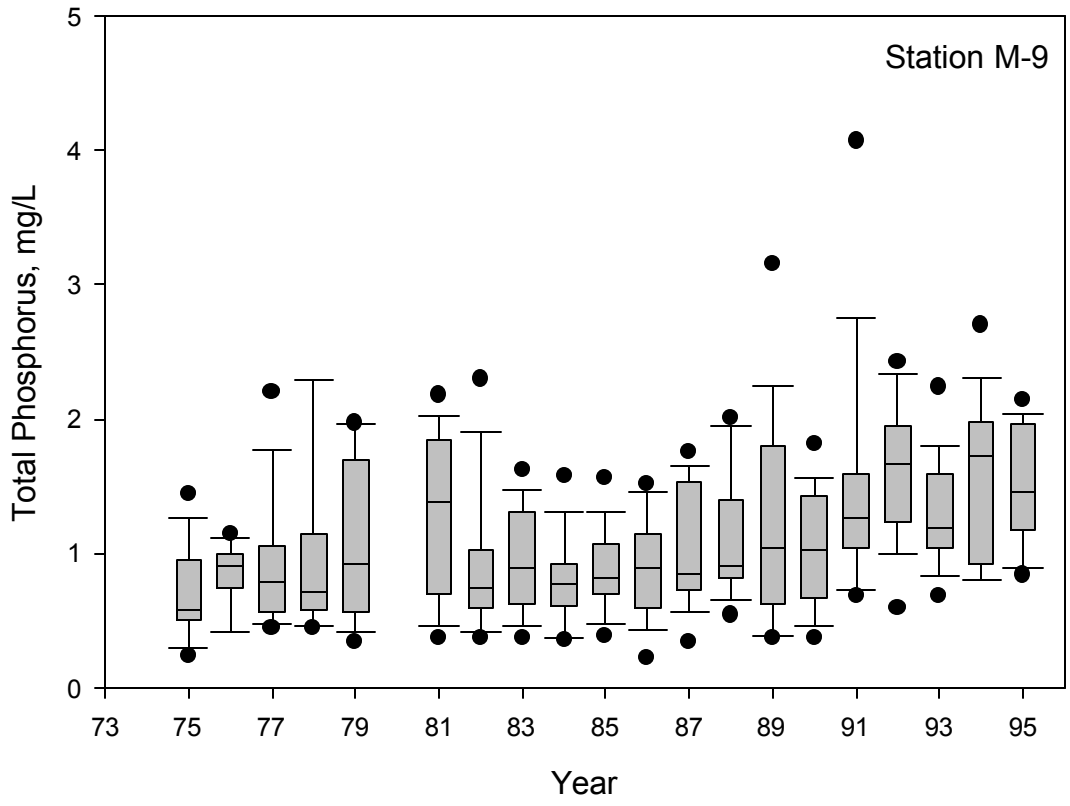

Figure J-5. Total Phosphorus (P) at Route 83 (M-9)
in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

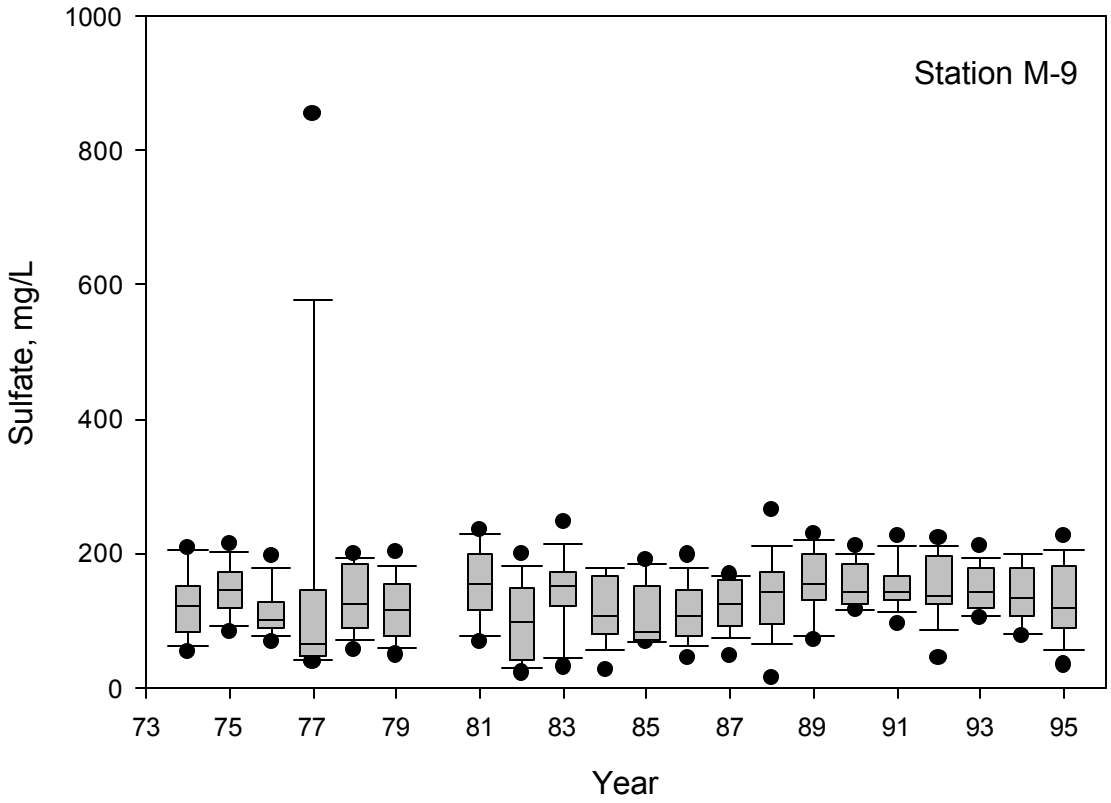

Figure J-6. Sulfate (SO_4) at Route 83 (M-9) in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

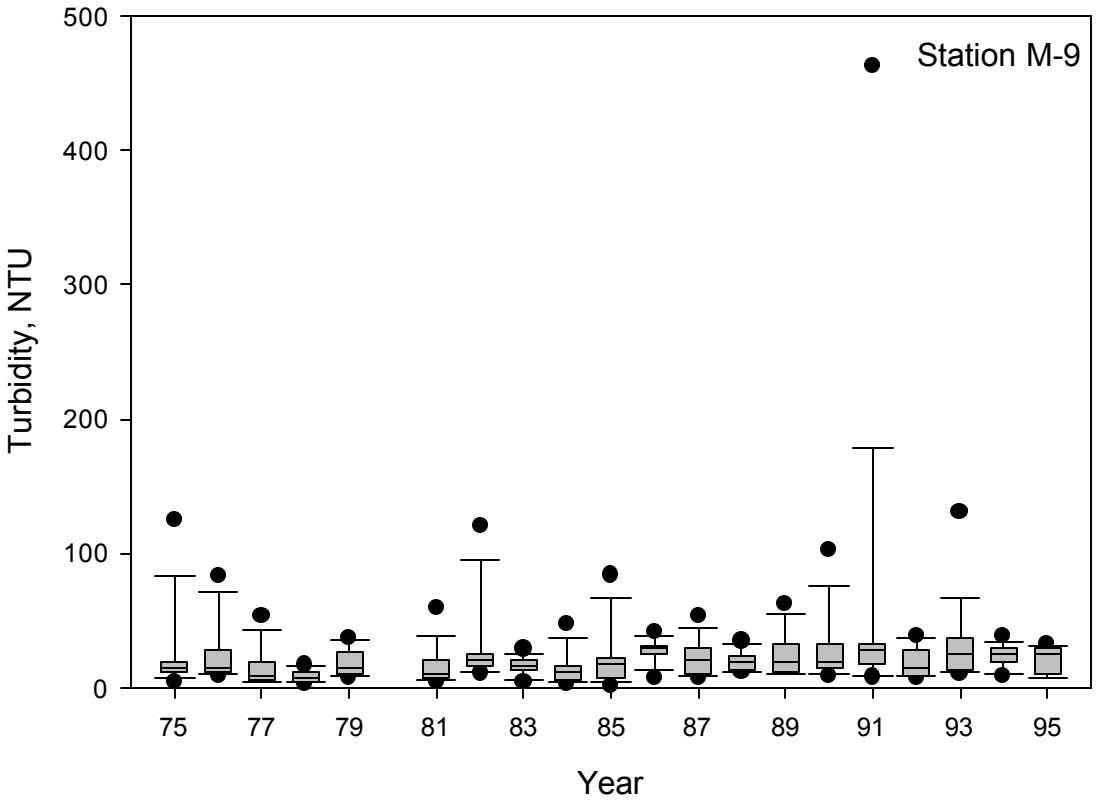

Figure J-7. Turbidity at Route 83 (M-9) in the
Cal-Sag Canal, 1975-1995. Data from MWRDGC.

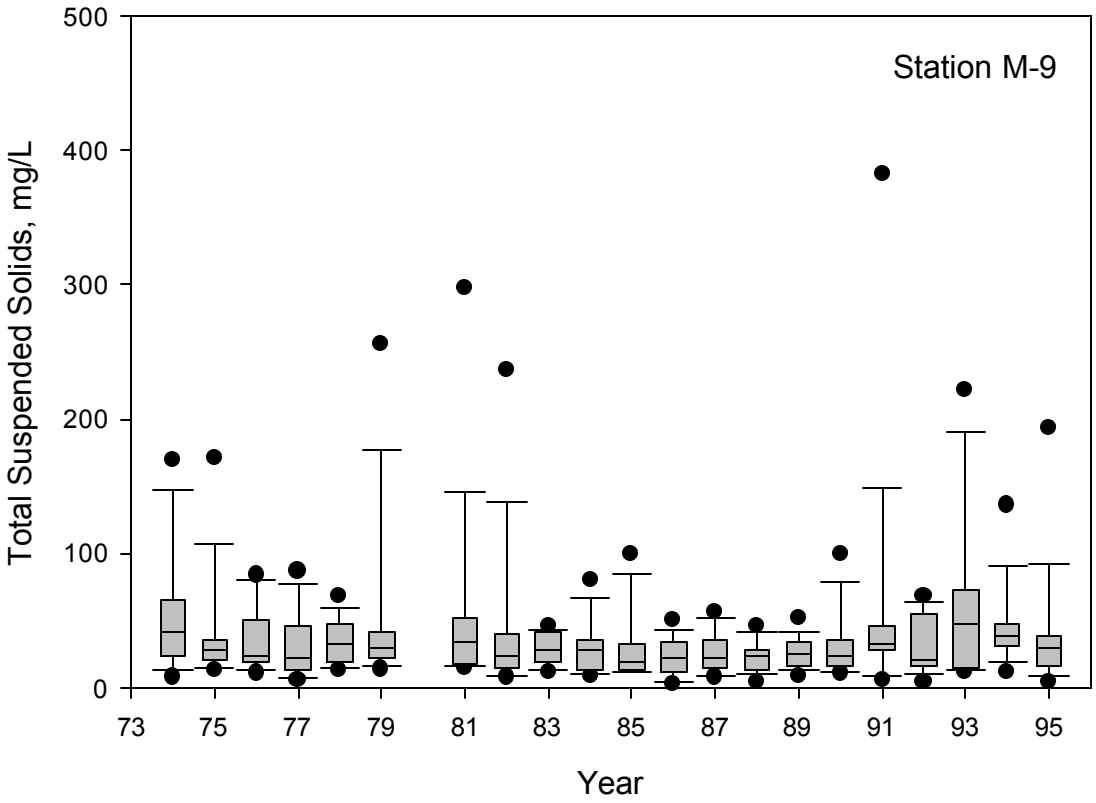

Figure J-8. Total Suspended Solids (TSS) at Route 83 (M-9)
in the Cal-Sag Canal, 1974-1995. Data from MWRDGC.

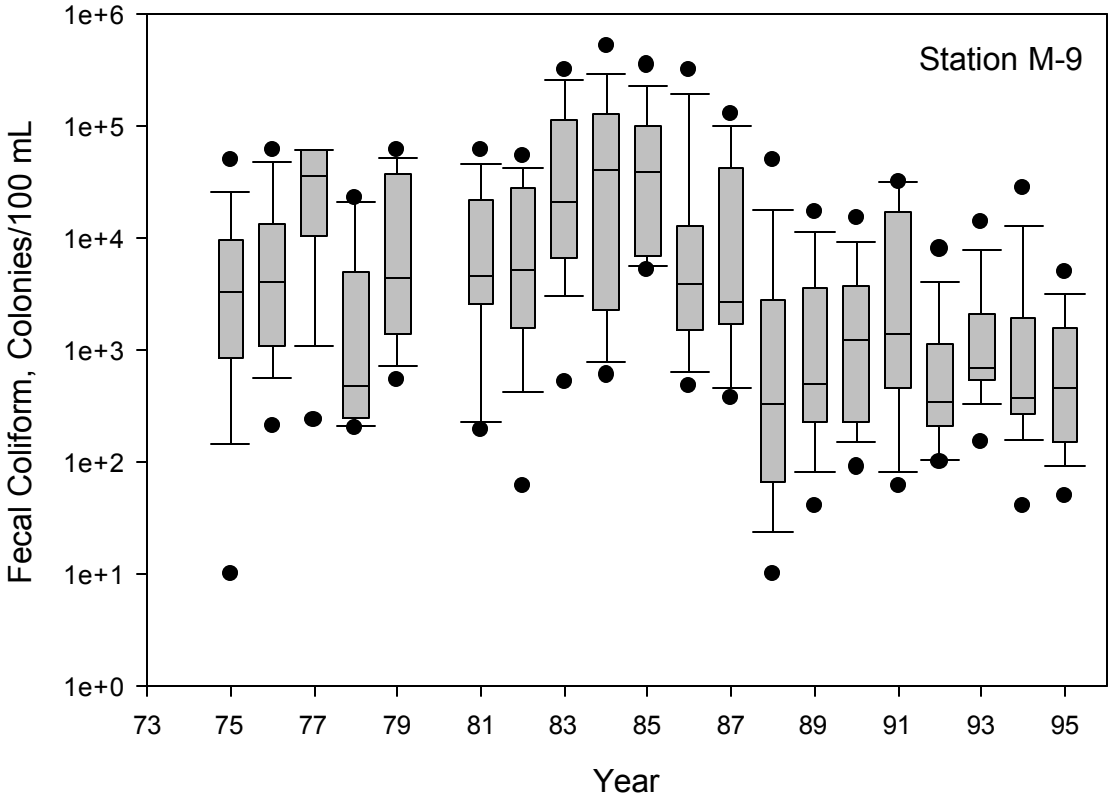

Figure J-9. Fecal Coliform Density at Route 83 (M-9)
in the Cal-Sag Canal, 1975-1995. Data from MWRDGC.

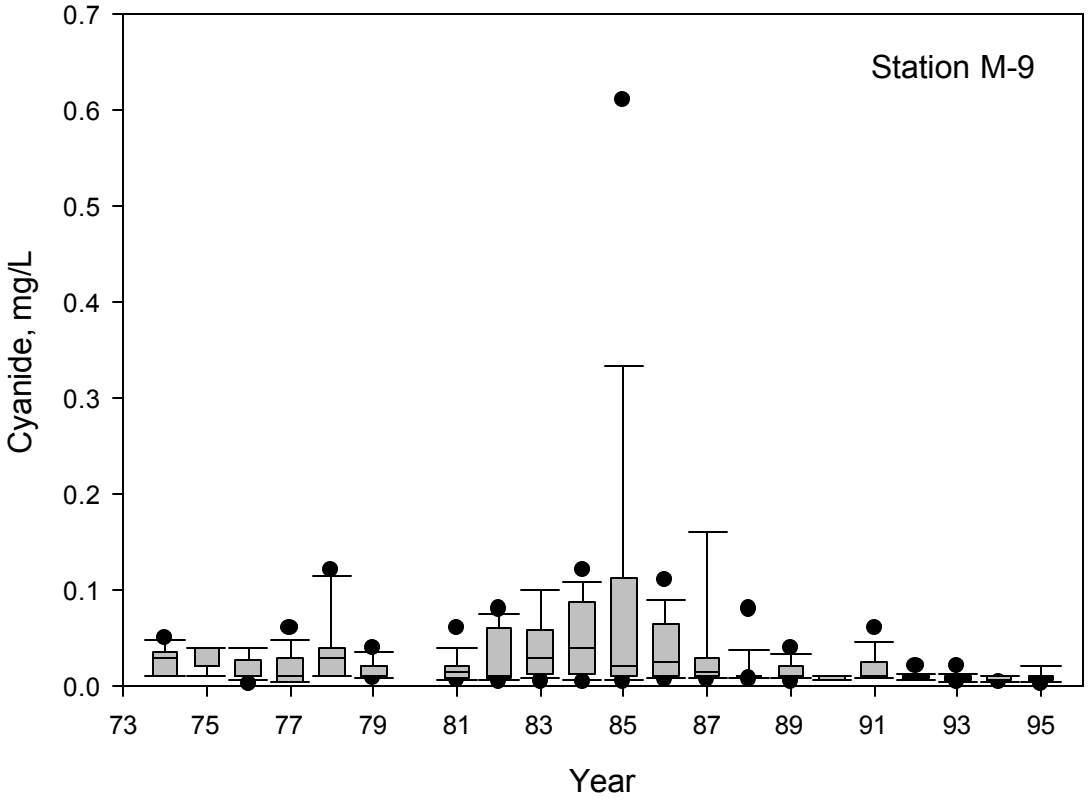

Figure J-10. Cyanide at Route 83 (M-9) in the
Cal-Sag Canal, 1974-1995. Data from MWRDGC.

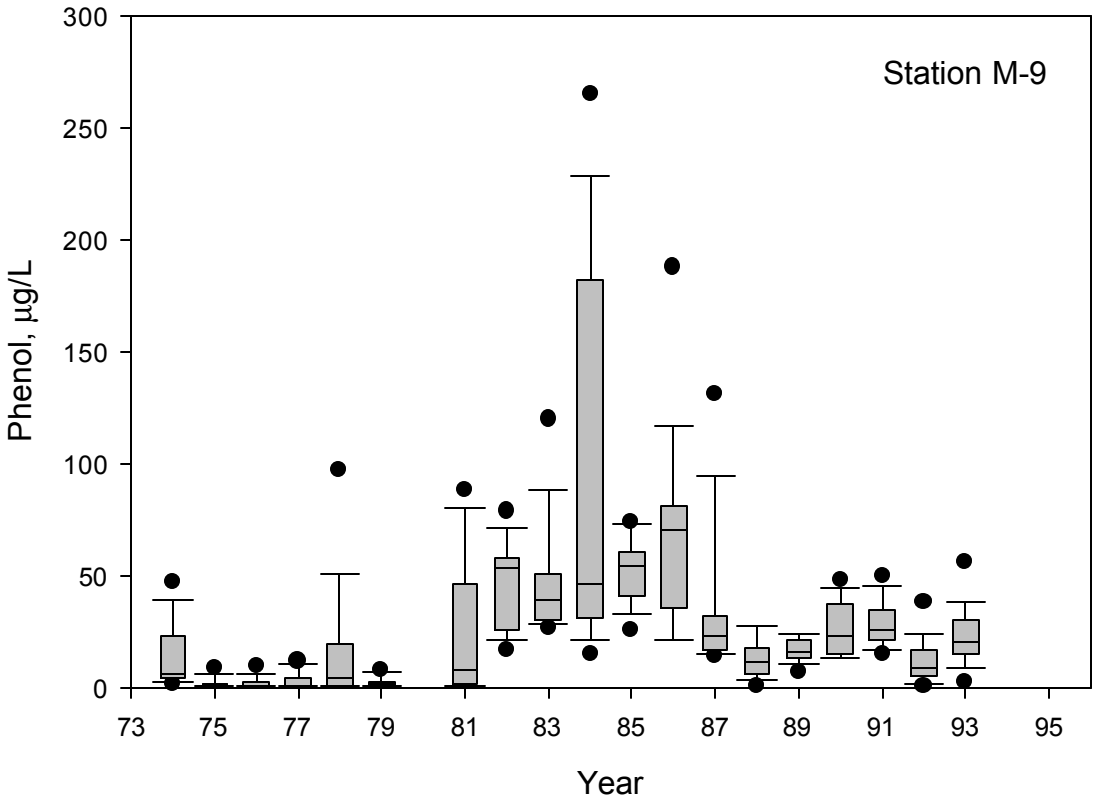

Figure J-11. Phenol at Route 83 (M-9) in the
Cal-Sag Canal, 1974-1993. Data from MWRDGC.

Appendix K. Box Plots for Station M-10, Chicago Sanitary and Ship Canal at Stephens St.

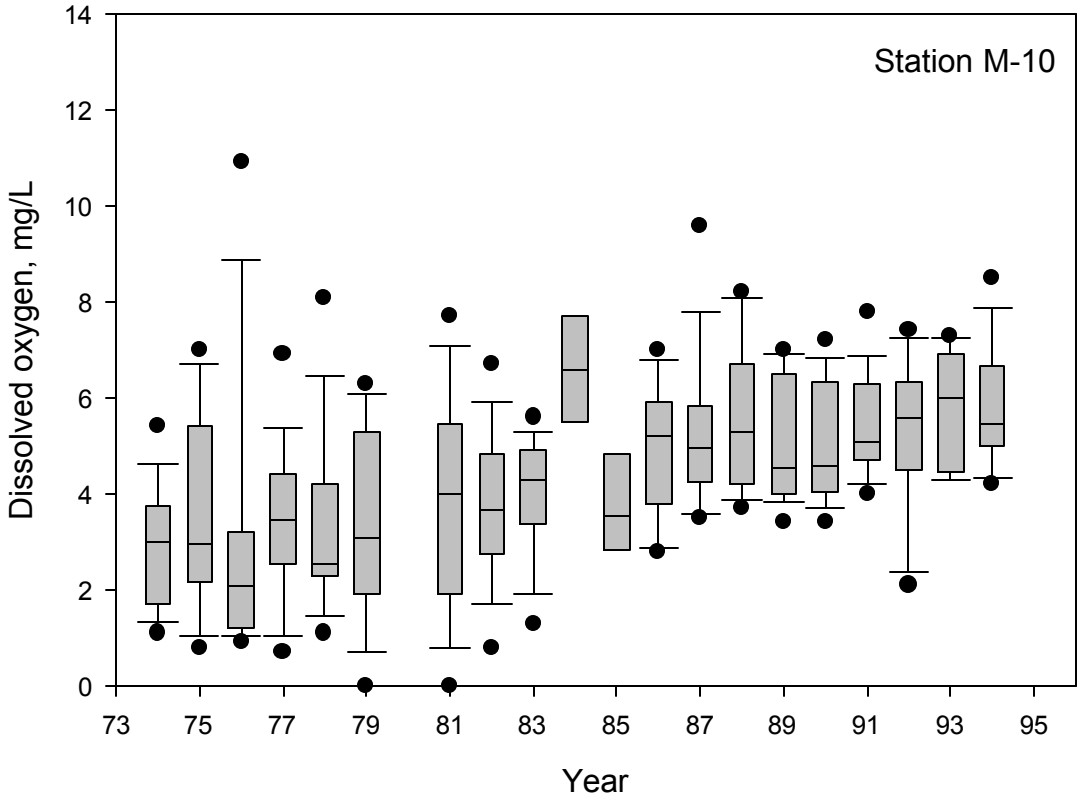

Figure K-1. Dissolved Oxygen (DO) at Stephens St. (M-10)
in the Chicago Sanitary and Ship Canal, 1974-1994. Data from MWRDGC.

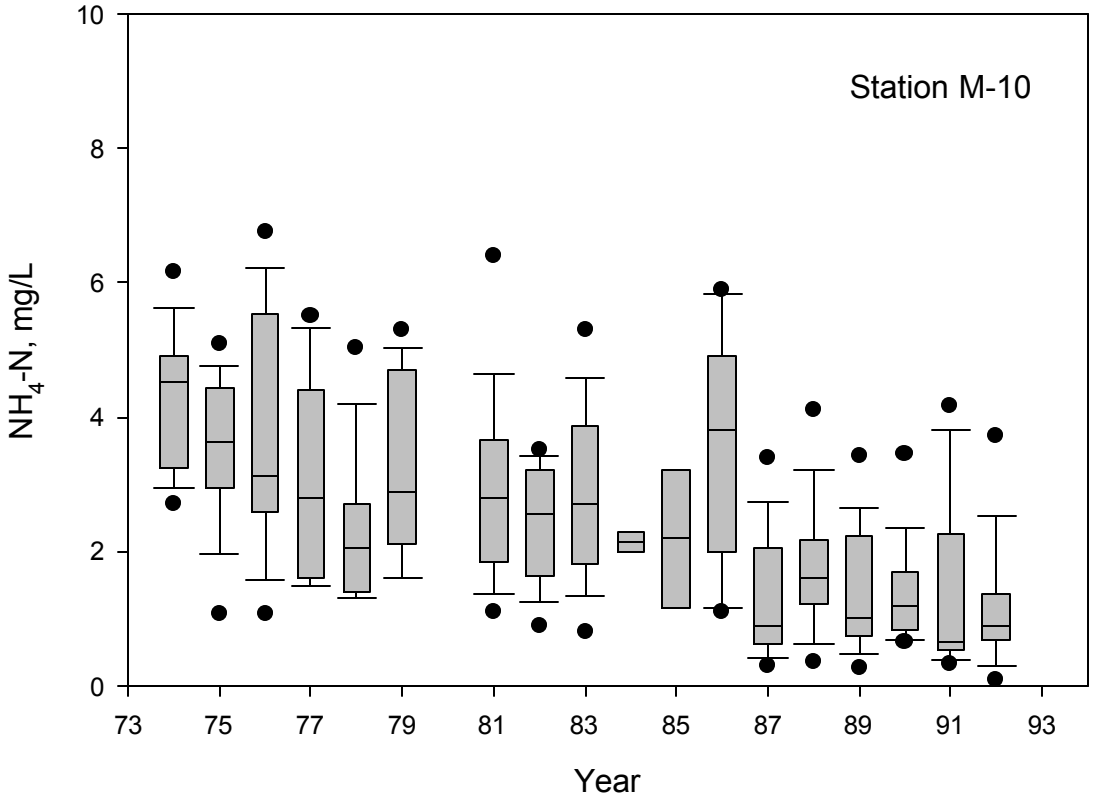

Figure K-2. Ammonia-Nitrogen (NH_4-N) at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1993. Data from MWRDGC.

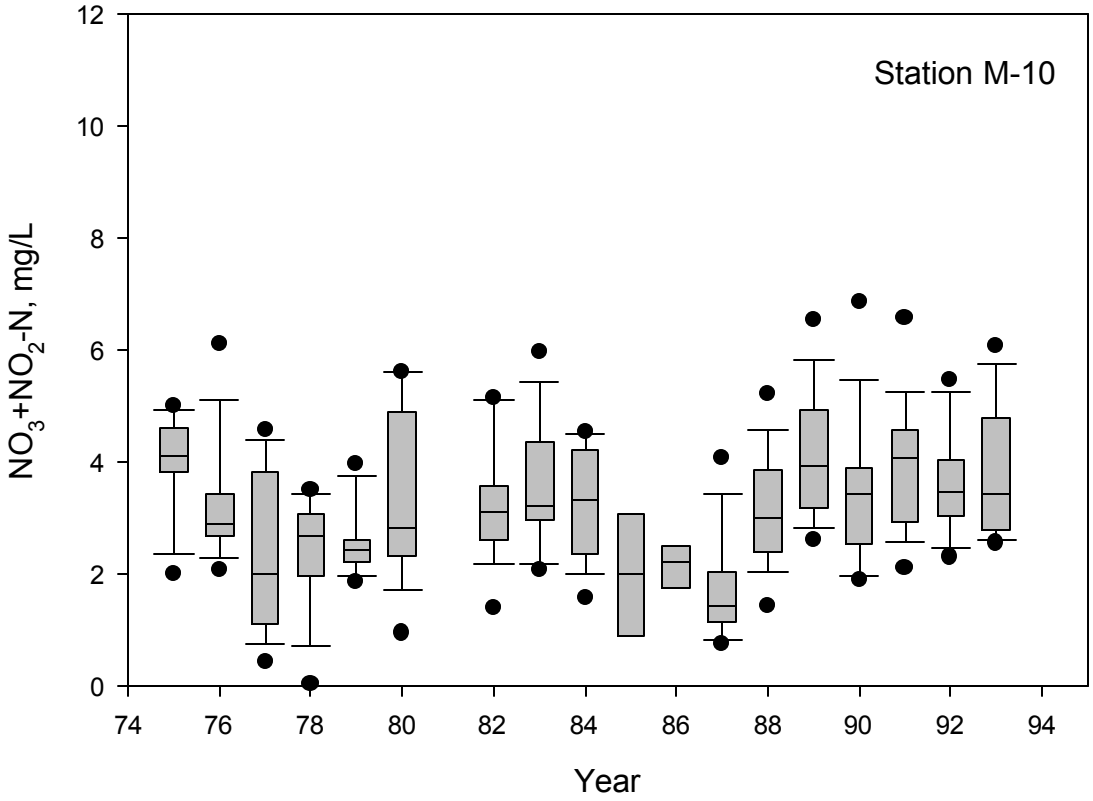

Figure K-3. Nitrate and Nitrite-Nitrogen (NO_3+NO_2-N) at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1993. Data from MWRDGC.

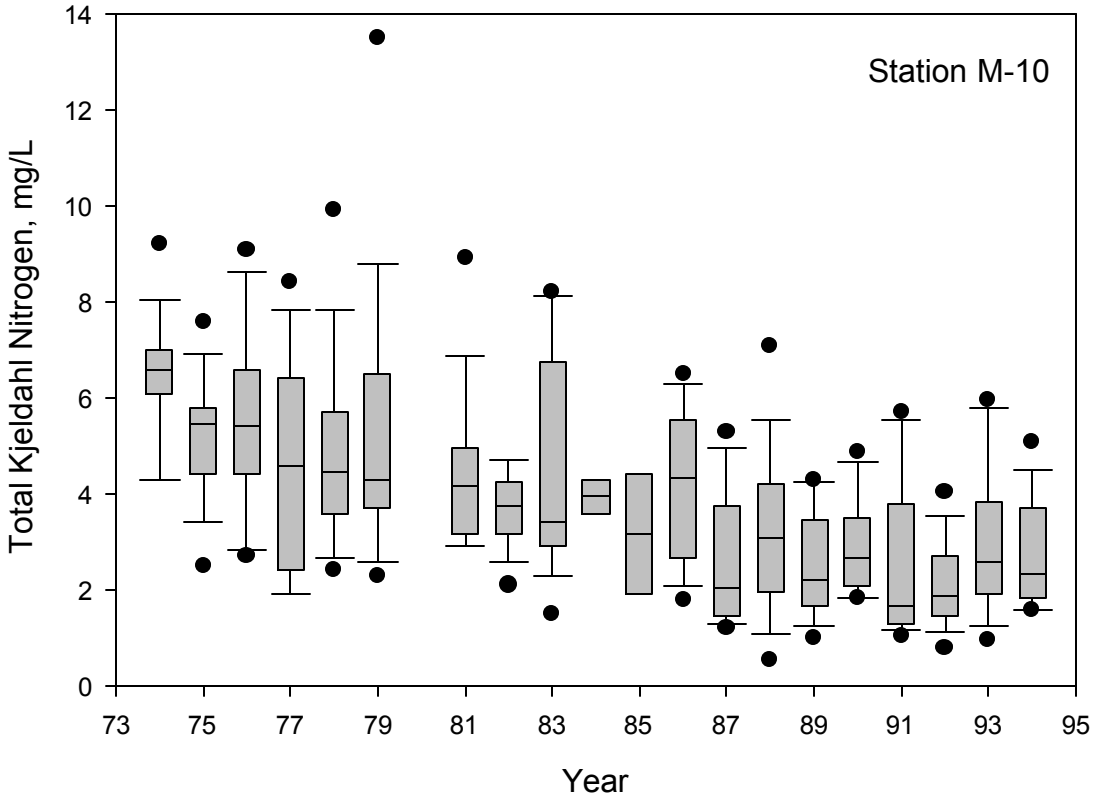

Figure K-4. Total Kjeldahl Nitrogen (TKN) at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1993. Data from MWRDGC.

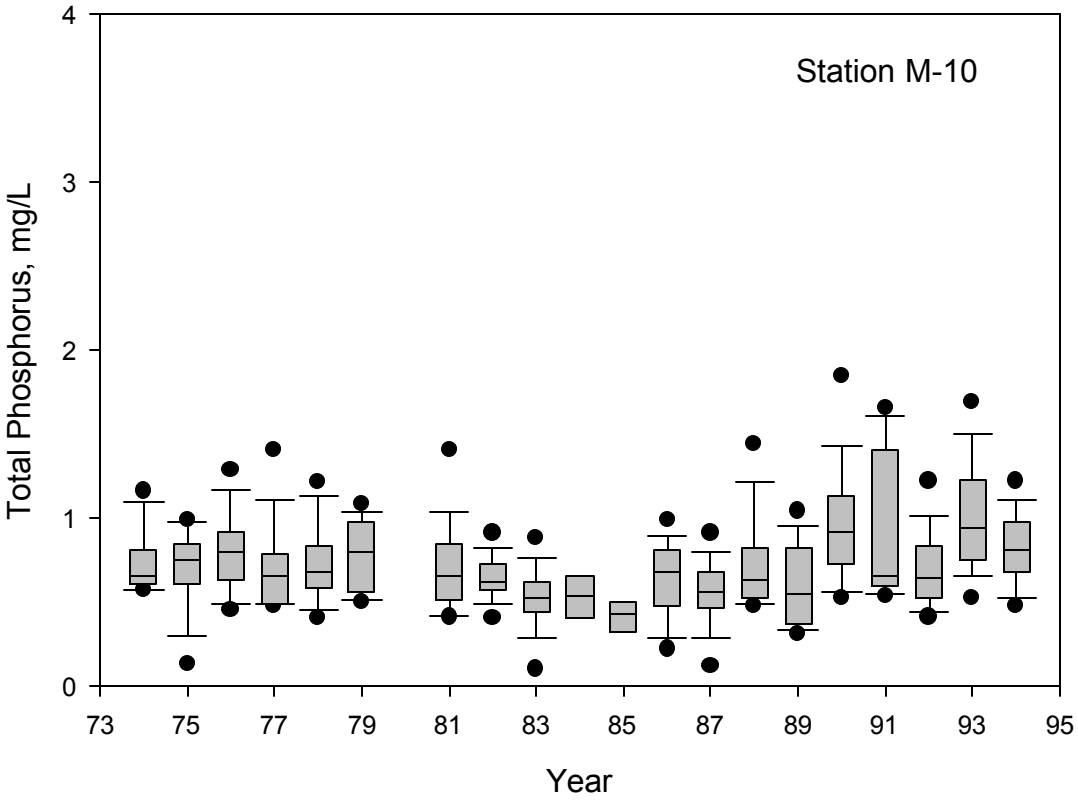

Figure K-5. Total Phosphorus (P) at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1993. Data from MWRDGC.

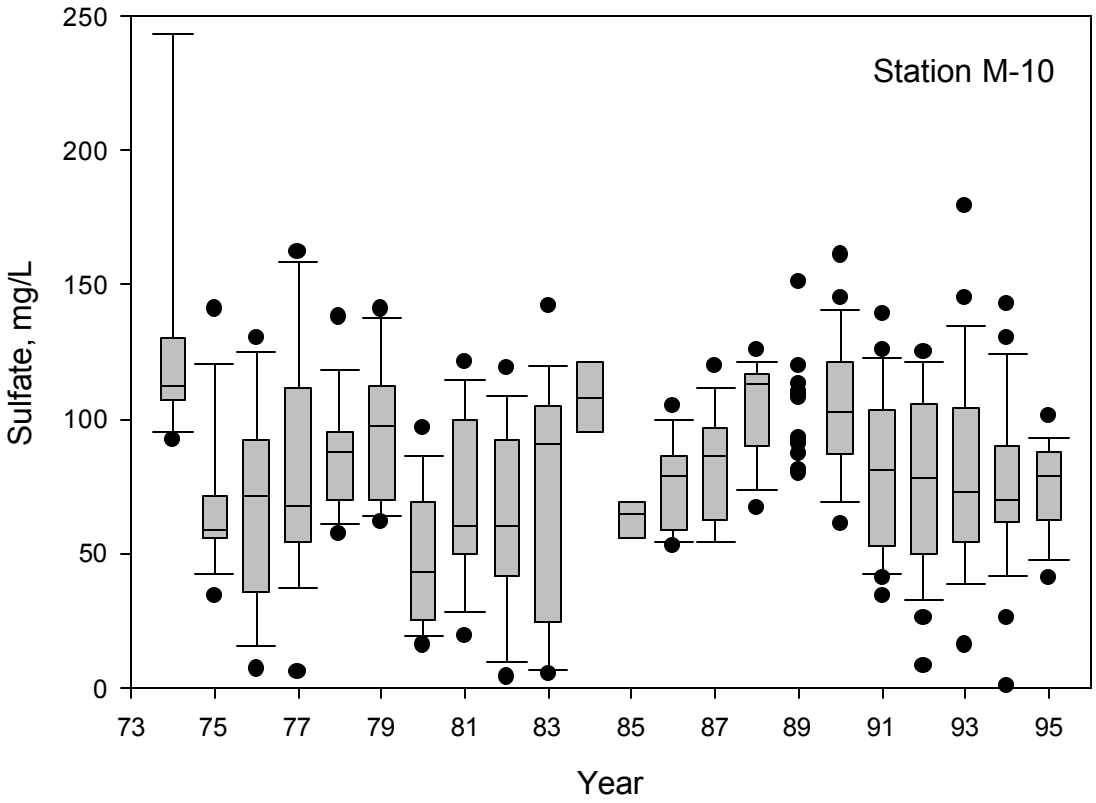

Figure K-6. Sulfate (SO_4) at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1995. Data from MWRDGC.

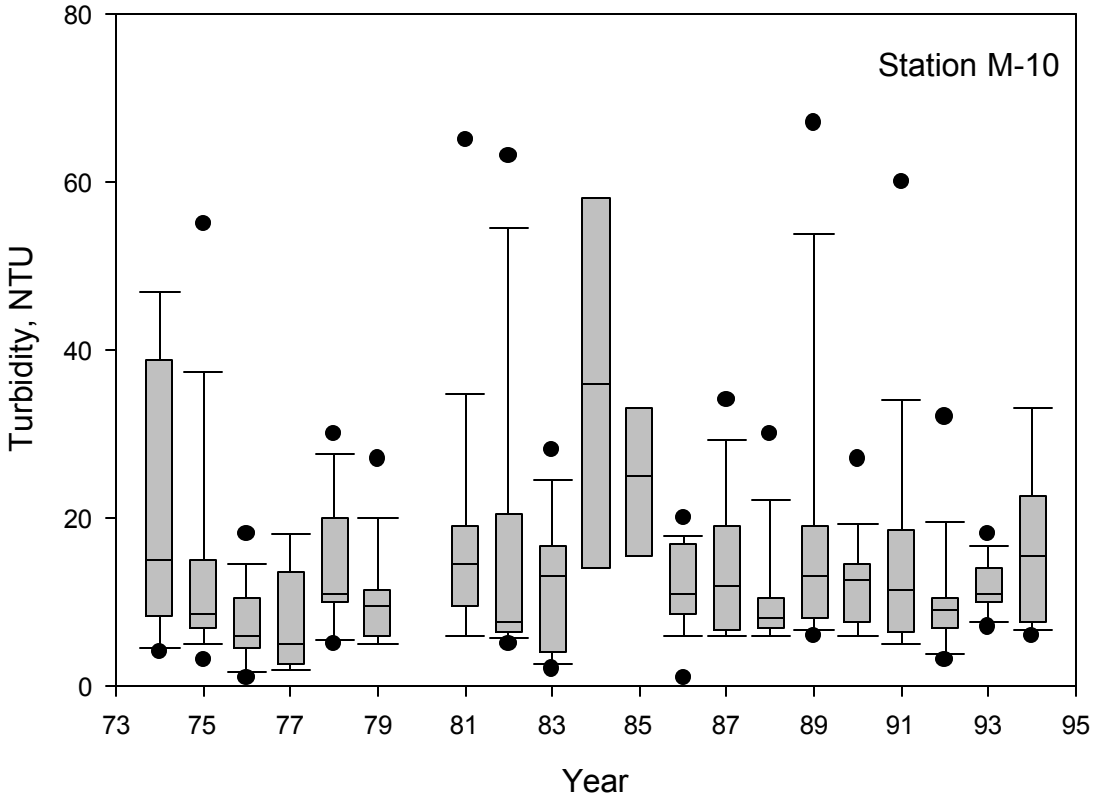

Figure K-7. Turbidity at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1995. Data from MWRDGC.

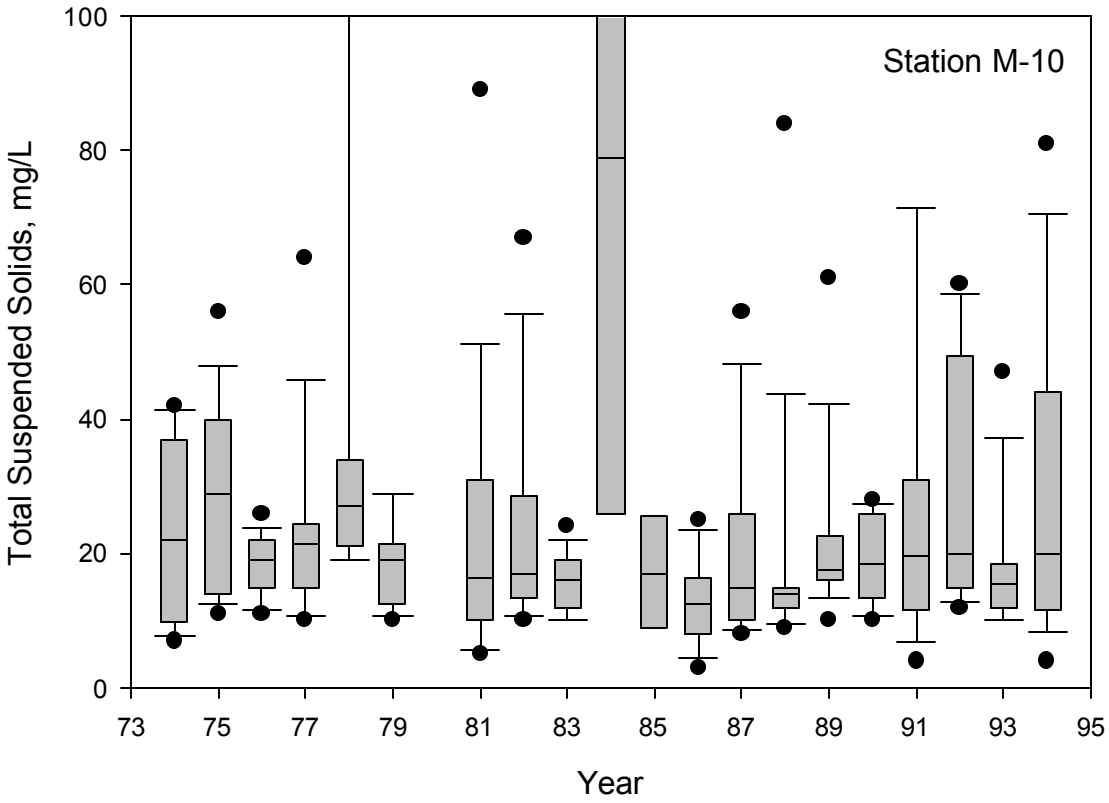

Figure K-8. Total Suspended Solids (TSS) at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1994. Data from MWRDGC.

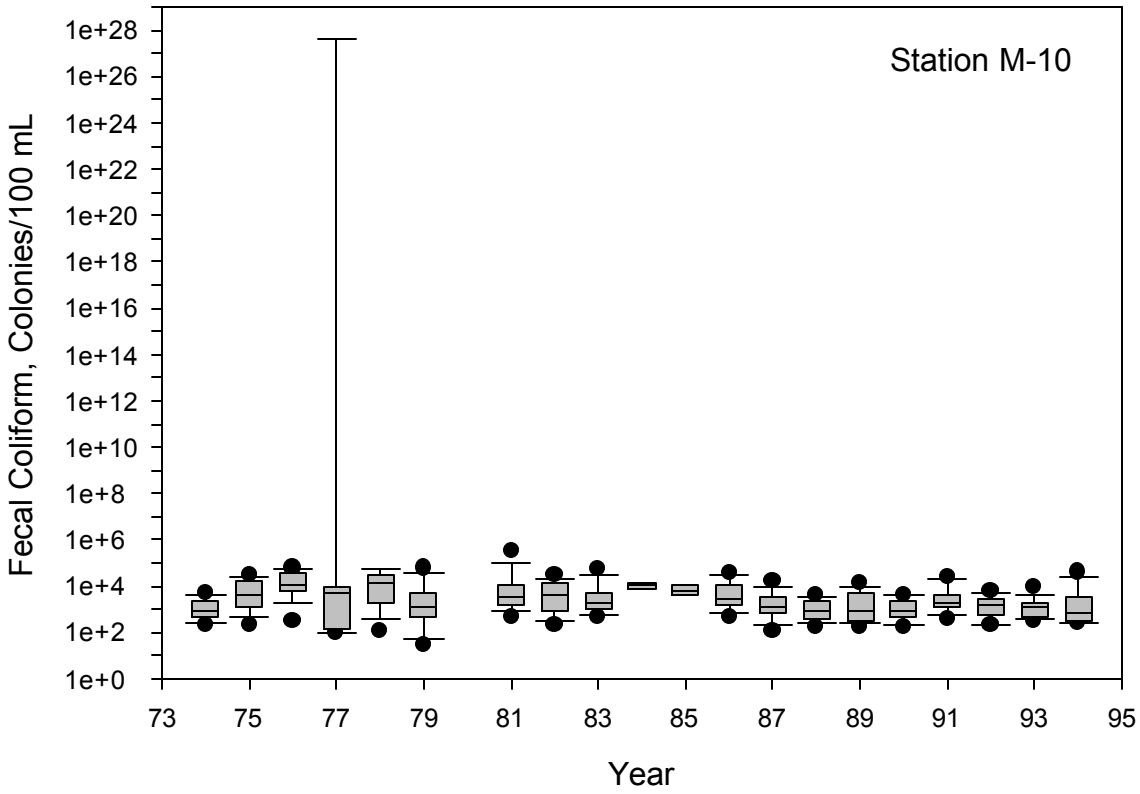

Figure K-9. Fecal Coliform Density at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1994. Data from MWRDGC.

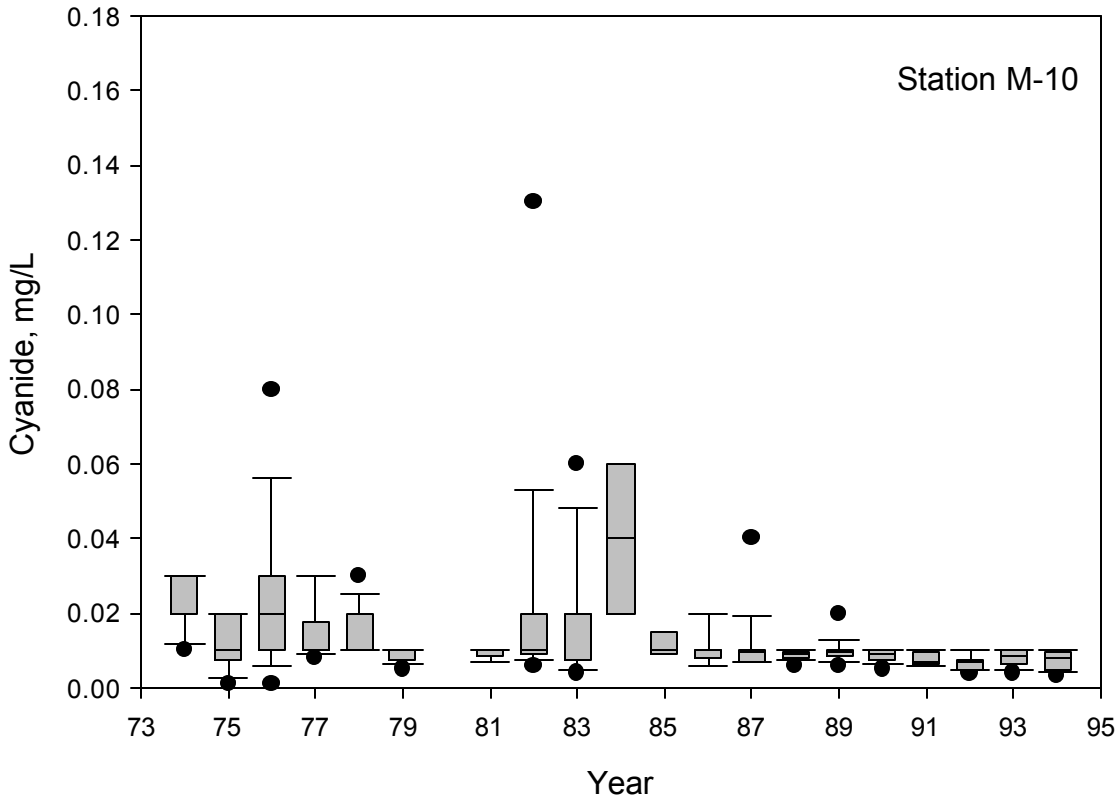

Figure K-10. Cyanide at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1994. Data from MWRDGC.

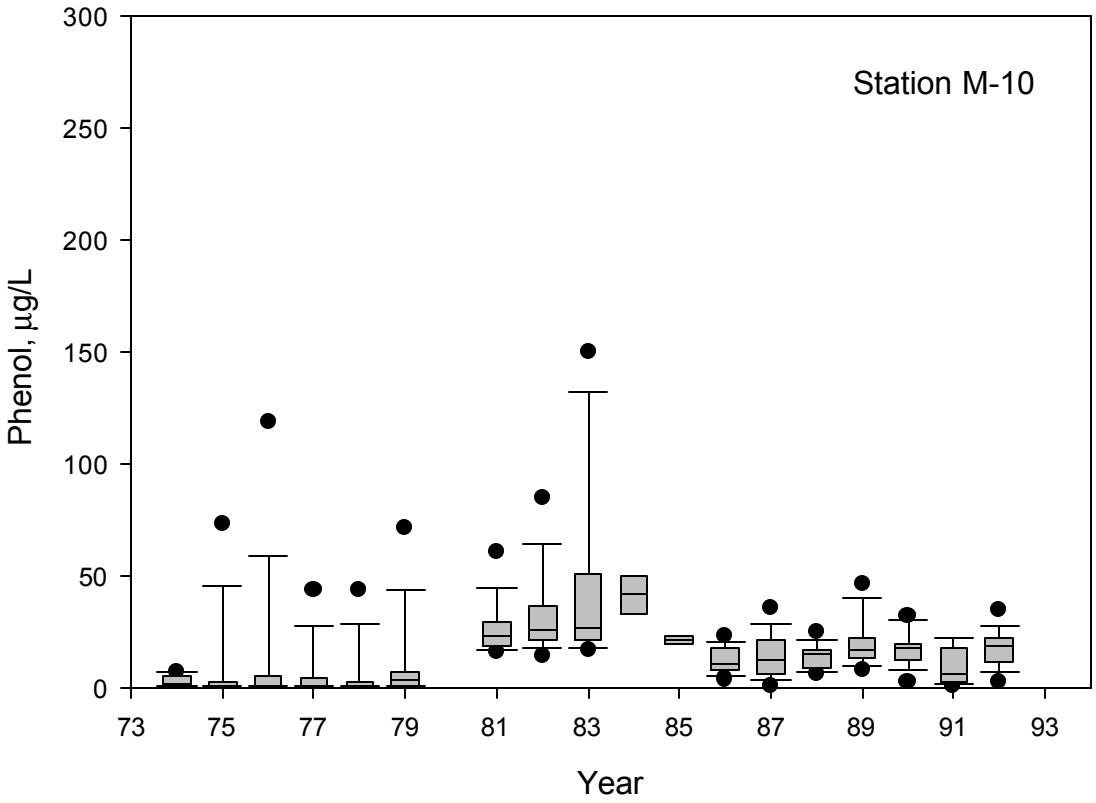

Figure K-11. Phenol at Stephens St. (M-10) in the Chicago Sanitary and Ship Canal, 1974-1992. Data from MWRDGC.

Appendix L. Box Plots for Station I-11, Chicago Sanitary and Ship Canal at Romeoville

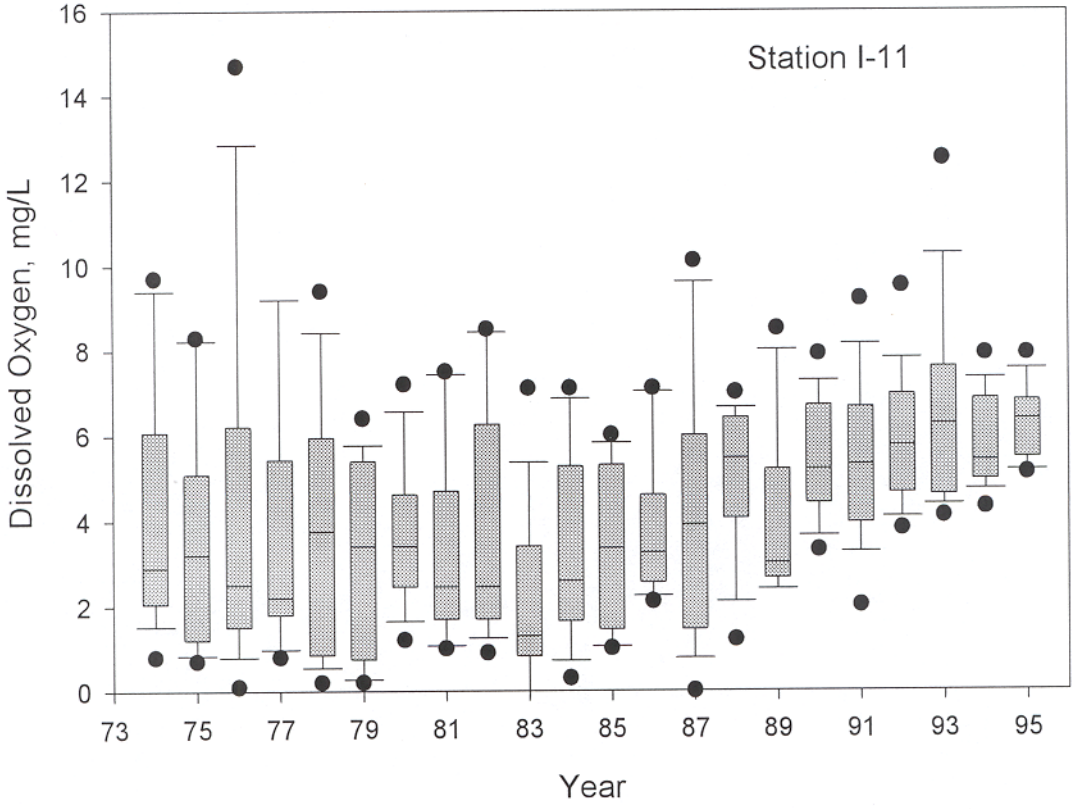

Figure L-1. Dissolved Oxygen (DO) at Romeville (I-11) in the Chicago Sanitary and Ship Canal, 1974 - 1995. Data from Illinois EPA.

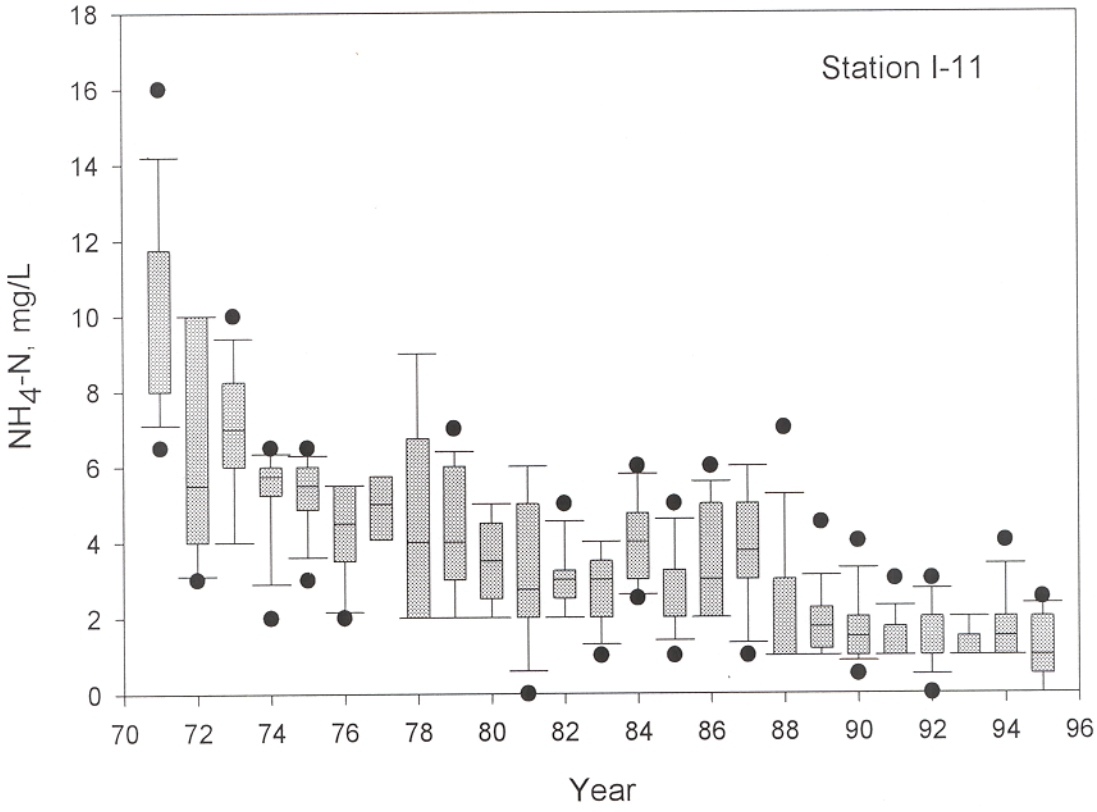

Figure L-2. Ammonia Nitrogen (NH_4-N) at Romeoville (I-11) in the Chicago Sanitary and Ship Canal, 1971-1995. Data from Illinois EPA.

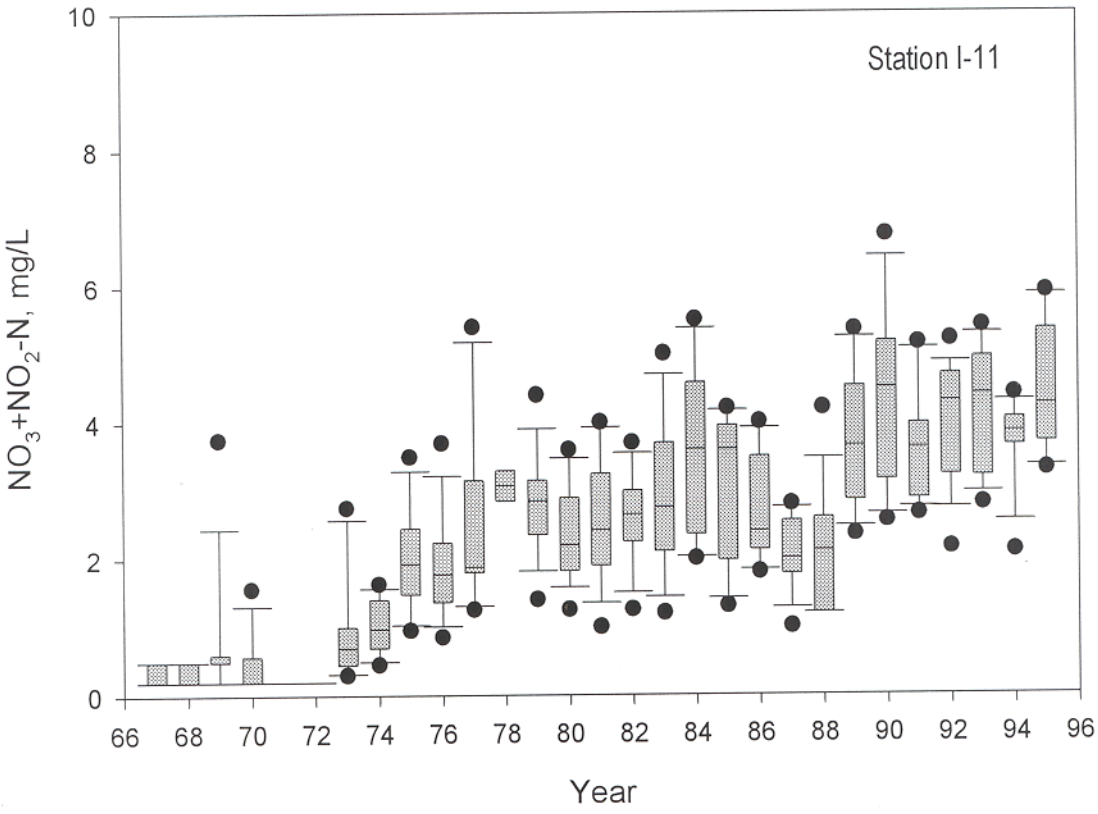

Figure L-3. Nitrate and Nitrite Ammonia (NO_3+NO_2-N) at Romeoville in the Chicago Sanitary and Ship Canal, 1967 - 1995. Data from the Illinois EPA.

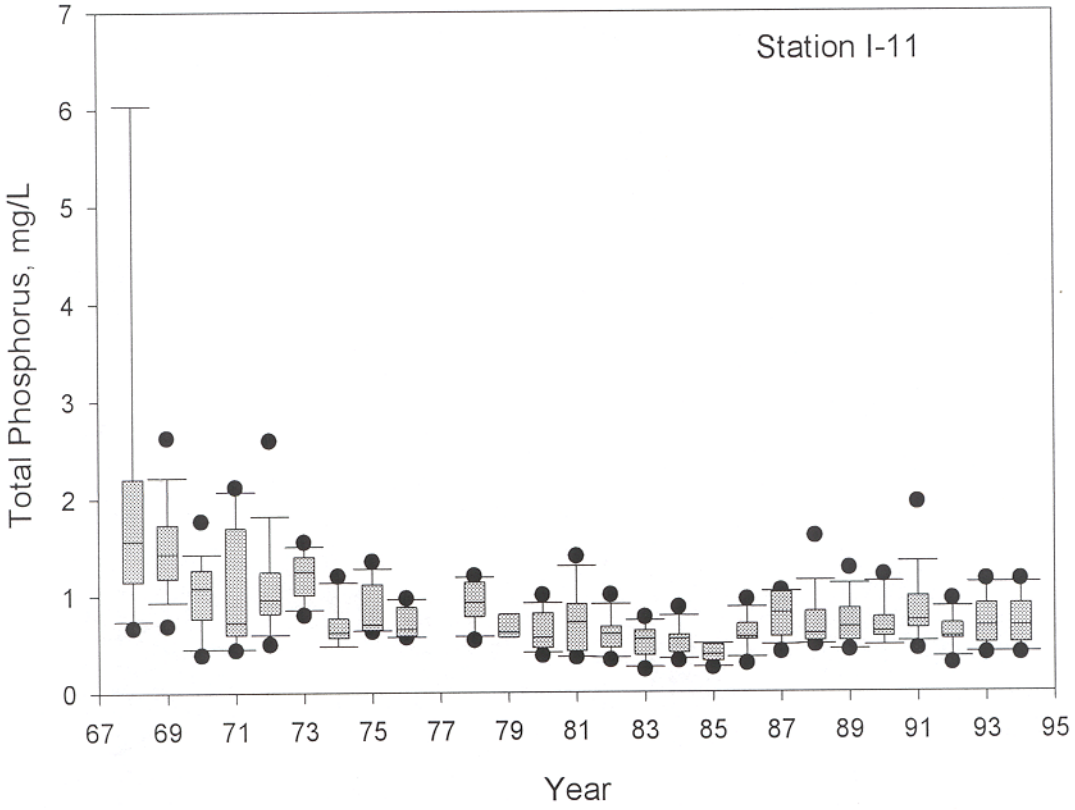

Figure L-4. Total Phosphorus (PO_4) at Romeoville (I-11) in the Chicago Sanitary and Ship Canal, 1968 to 1995. Data from Illinois EPA.

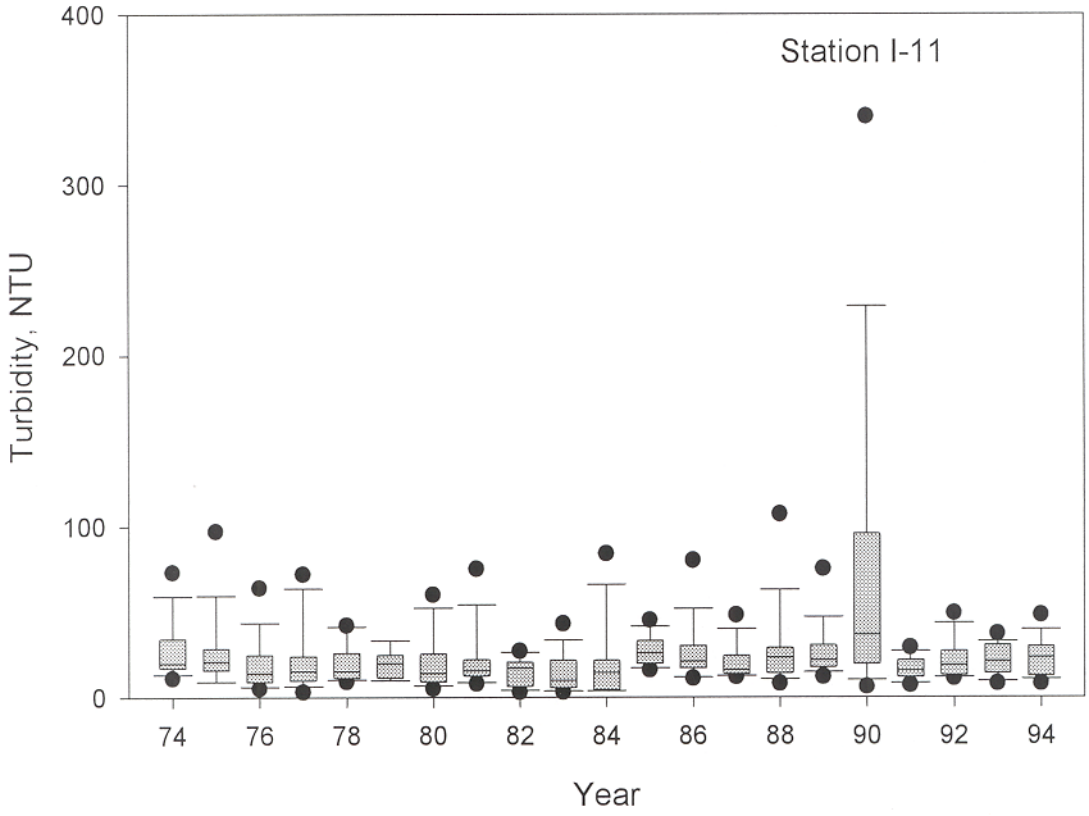

Figure L-5. Turbidity at Romeoville (I-11) in the Chicago Sanitary and Ship Canal, 1974-1994. Data from the Illinois EPA.

Appendix M. Box Plots for Station G-12, Illinois River at Marseilles

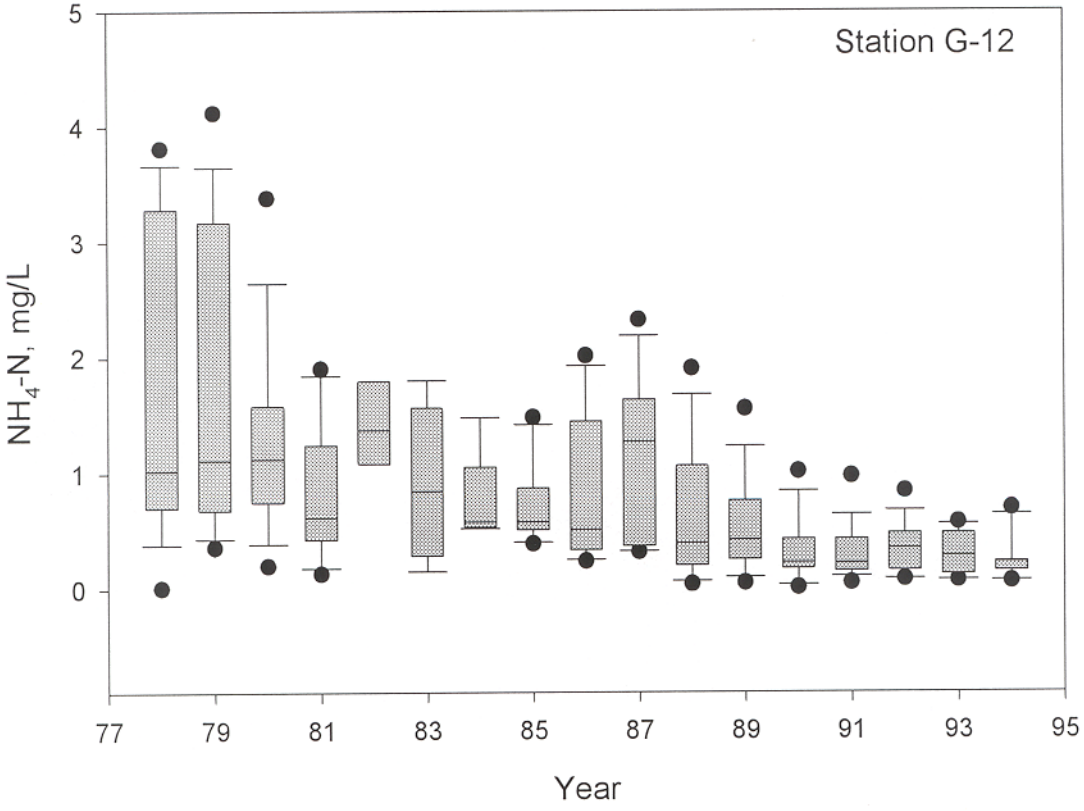

Figure M-1. Ammonia Nitrogen (NH_4-N) at the Illinois River at Marseilles (G-12), 1978-1995. Data from US Geological Survey.

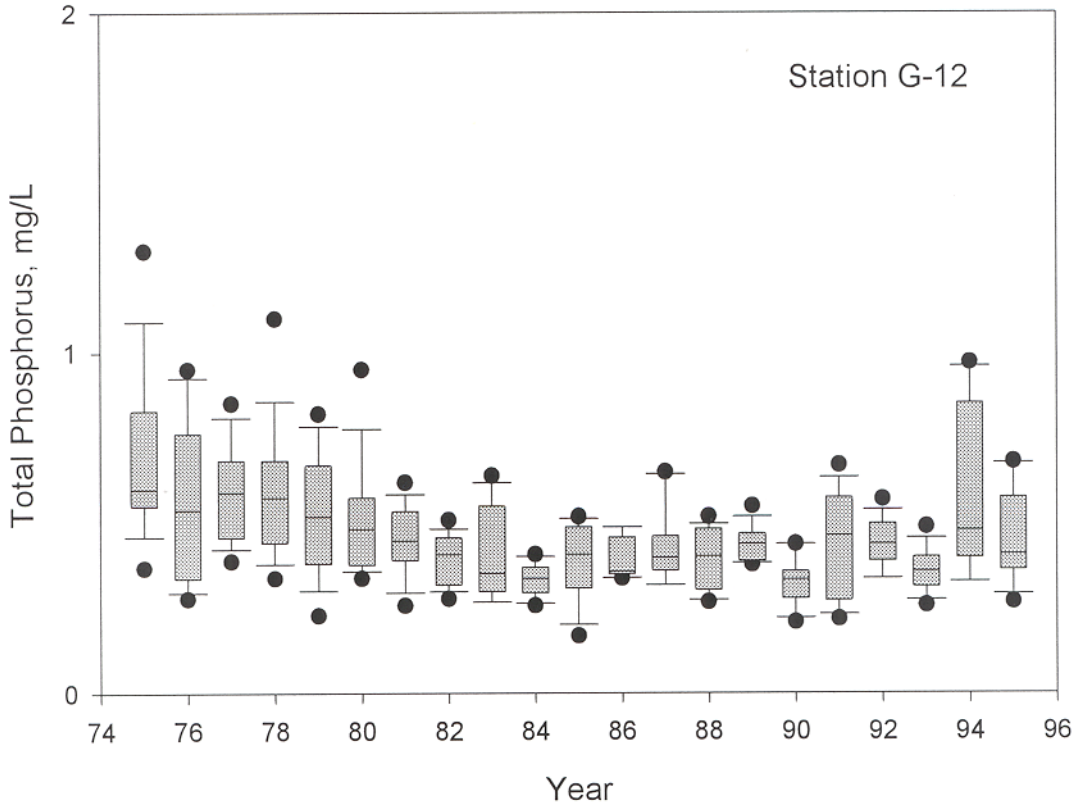

Figure M-2. Total Phosphorus (P) at the Illinois River at Marseilles (G-12), 1975 - 1995. Data from US Geological Survey.

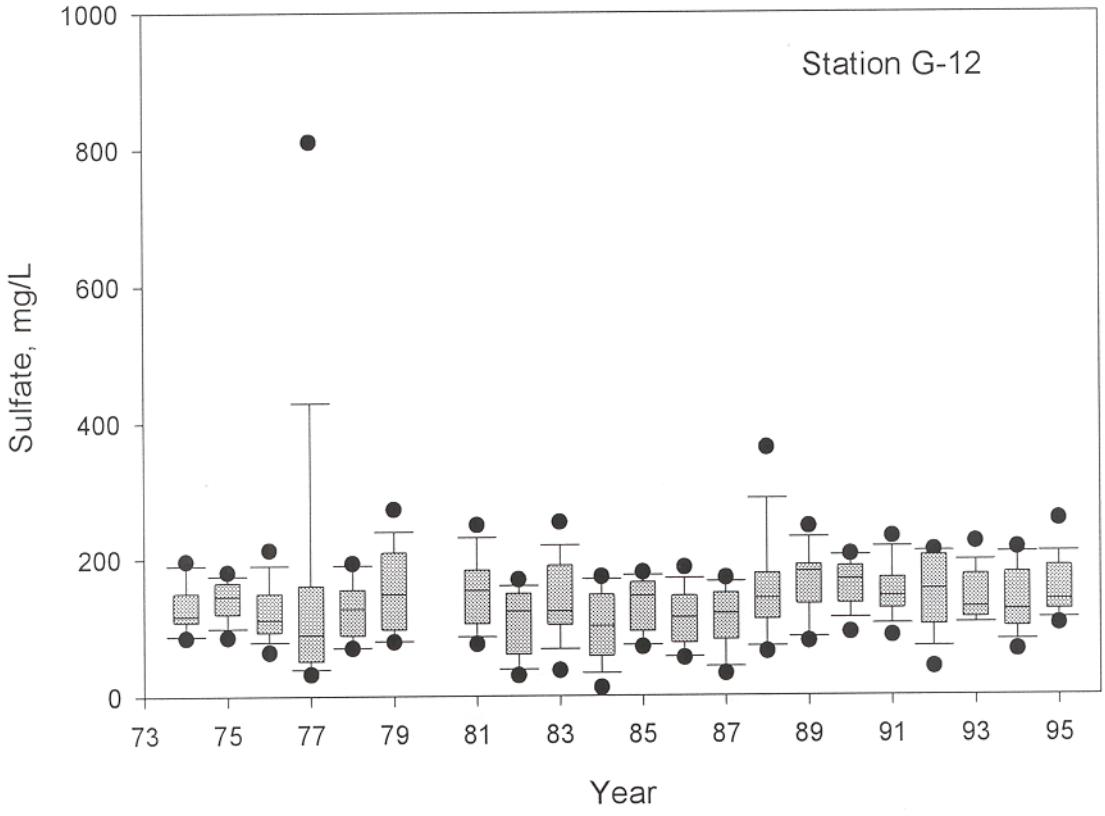

Figure M-3. Sulfate (SO_4) at the Illinois River at Marseilles (G-12), 1978-1995. Data from US Geological Survey.

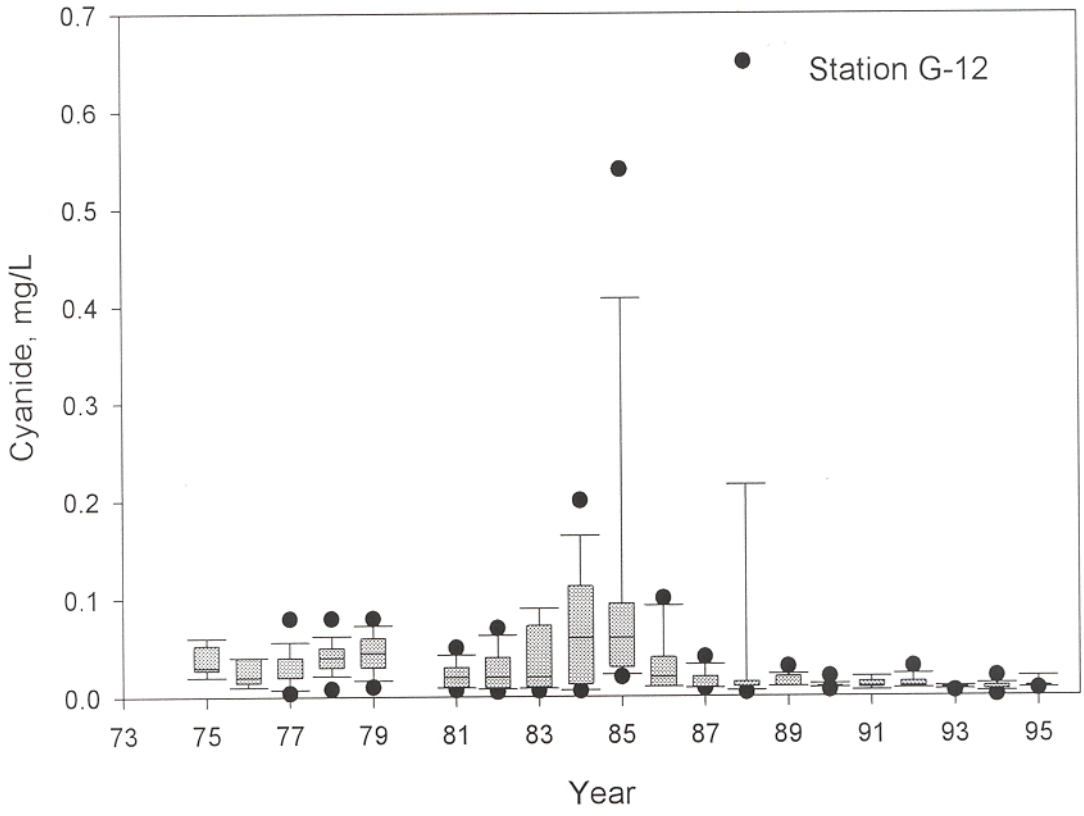

Figure M-4. Cyanide at the Illinois River at Marseilles (G-12). Data from the US Geological Survey.

Appendix N. Box Plots for Station S-13, Illinois River at Peoria

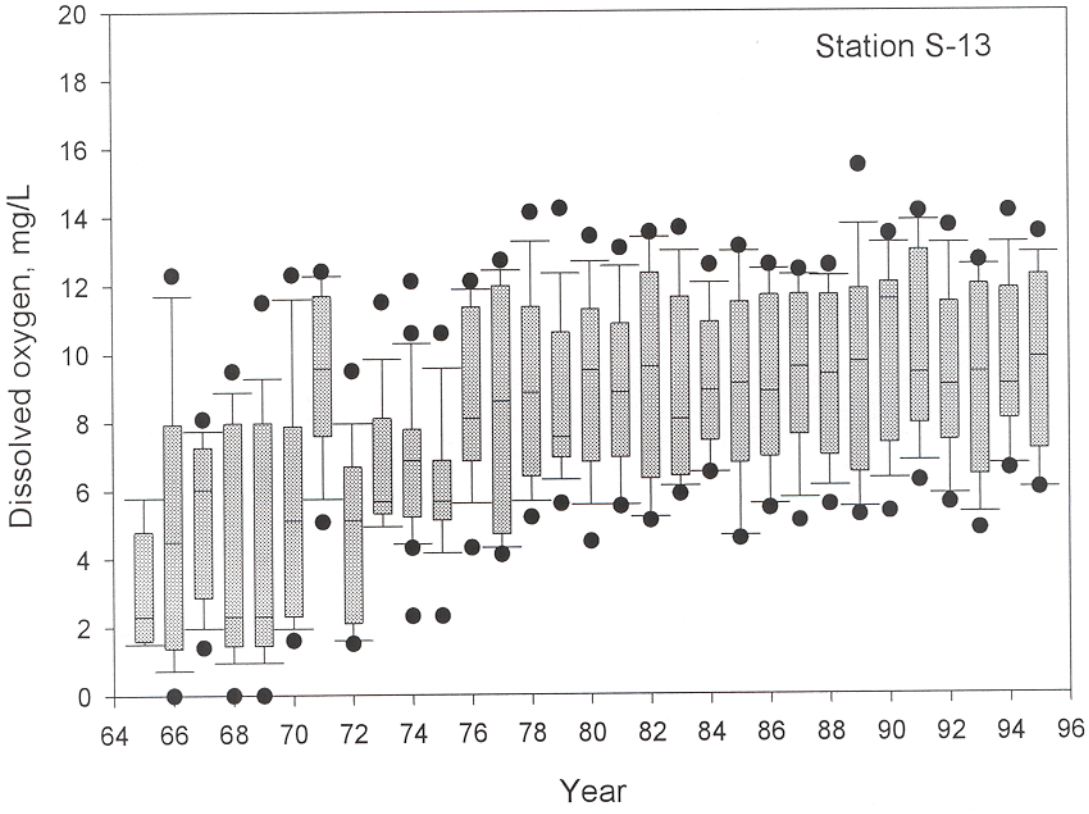

Figure N-1. Dissolved Oxygen (DO) at the Illinois River at Peoria (S-13). Data from the Illinois State Water Survey

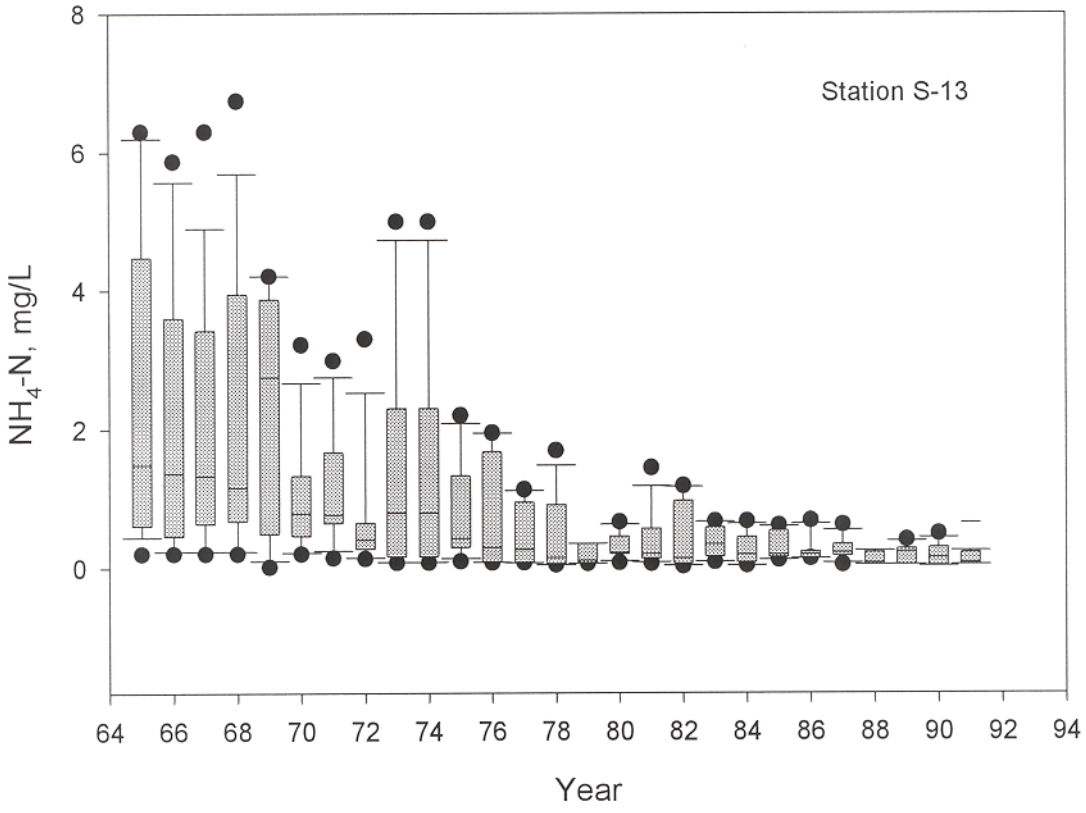

Figure N-2. Ammonia Nitrogen (NH_4-N) at Illinois River at Peoria (S-13)

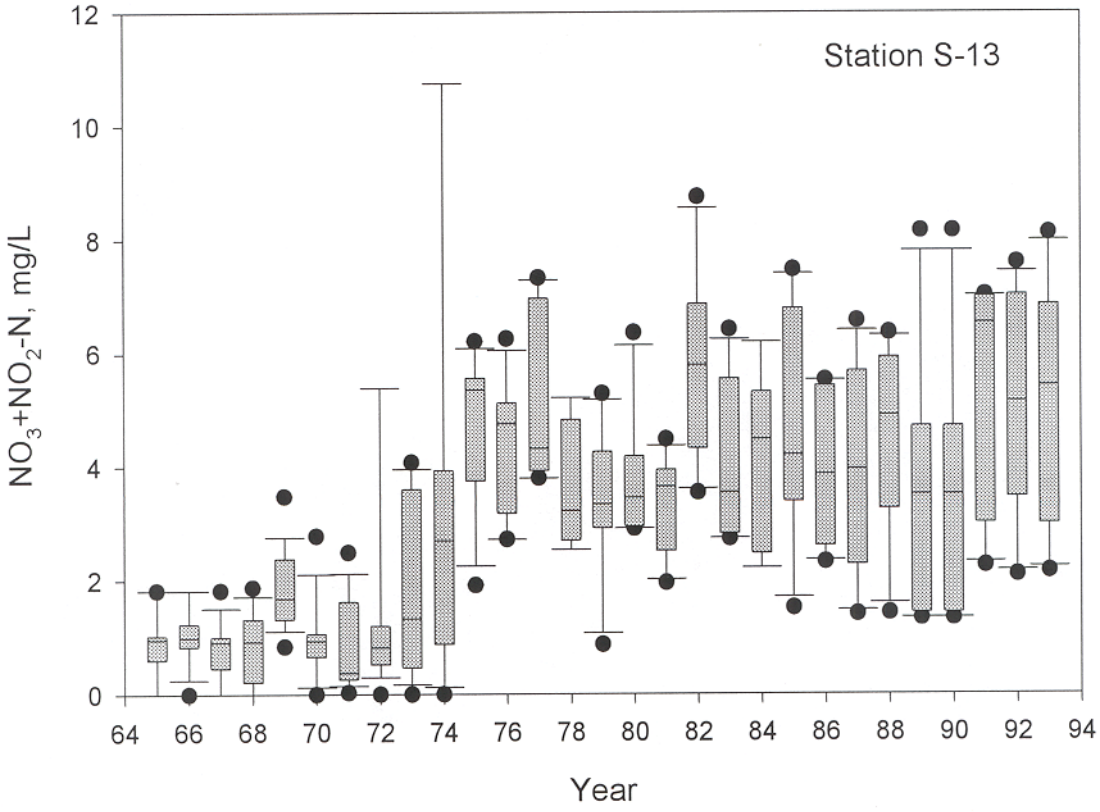

Figure N-3. Nitrate and Nitrite Nitrogen (NO_3+NO_2-N) at the Illinois River at Peoria (S-13). Data from the Illinois State Water Survey.


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